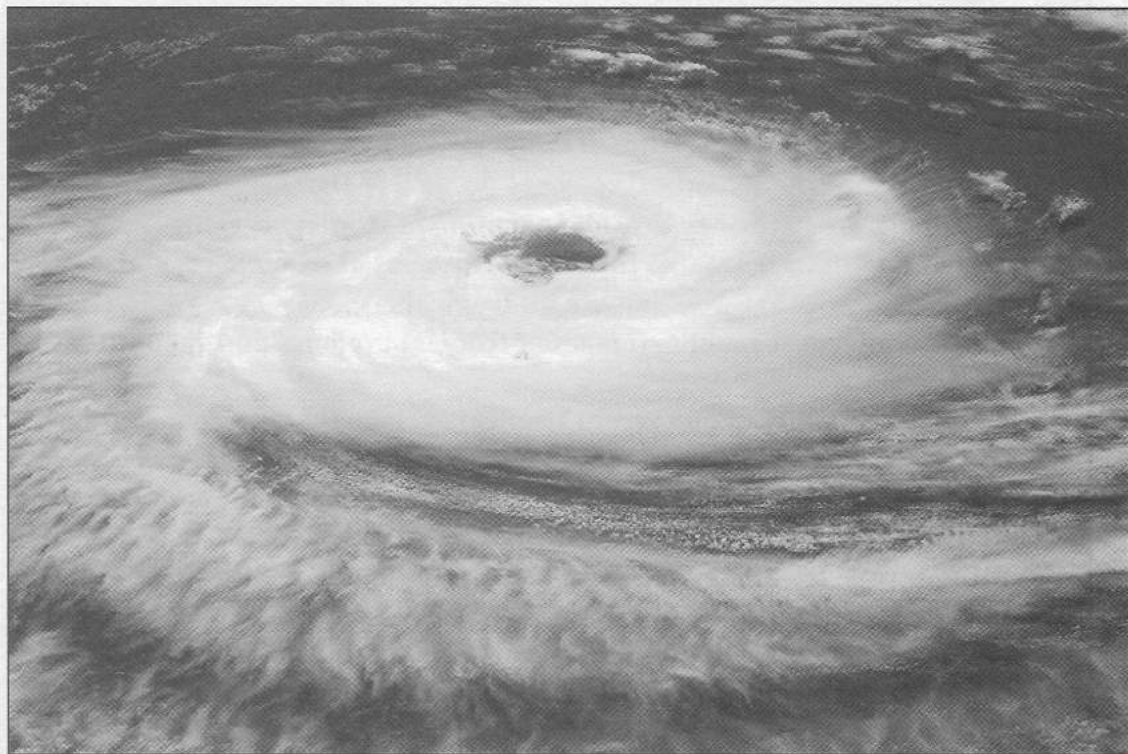


# **MODULE TWO**

## **CLIMATE AND WEATHER**



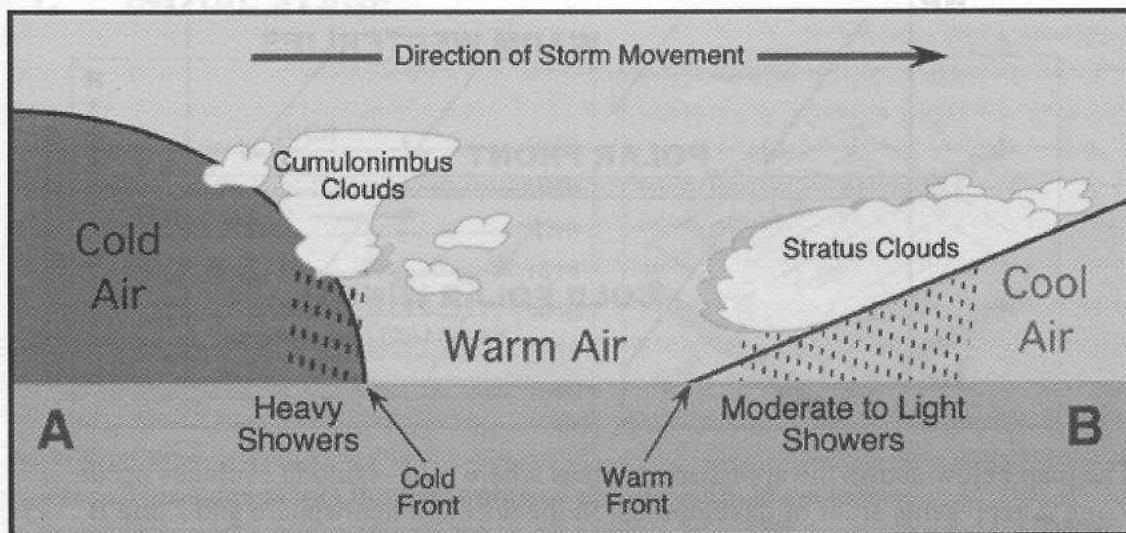
## **MODULE 2: CLIMATE AND WEATHER**

**By the end of this module, you should be able to:**

- list the general characteristics of mid - latitude cyclones
- identify areas where mid - latitude cyclones form
- explain conditions necessary for the formation of mid - latitude cyclones
- identify and describe stages in the development of mid - latitude cyclones and related weather conditions
- describe weather patterns associated with cold, warm, and occluded fronts
- describe the effects of mid - latitude cyclones on the climate of Southern Africa
- evaluate the impact of mid - latitude cyclones on human activities in South Africa
- formulate emergency measures that people should take in the event of an intense mid - latitude cyclone approaching
- read and interpret satellite images of mid - latitude cyclones , and synoptic weather maps
- list the general characteristics of tropical cyclones
- identify areas where tropical cyclones occur
- explain factors necessary for the formation of tropical cyclones
- identify and describe stages in the development of tropical cyclones
- describe the weather associated with tropical cyclones
- read and interpret satellite images of tropical cyclones and synoptic weather maps
- examine case study of one recent tropical cyclone that affected southern Africa
- evaluate the impact of tropical cyclones on human activities and the environment
- outline strategies that help to prepare for and manage the effects of tropical cyclones
- compare and contrast mid - latitude cyclones and tropical cyclones
- identify the location of high pressure cells that affect South Africa
- list the general characteristics of these high pressure cells
- describe anticyclonic air circulation around South Africa and its influence on weather and climate
- identify and describe the following travelling disturbances associated with anticyclonic circulation: moisture front, line thunderstorms, coastal low pressure systems and South African berg winds
- read and interpret satellite images and synoptic weather maps that illustrate weather associated with subtropical anticyclonic conditions
- explain the term micro - climate
- explain the effects of slope aspect
- explain the development of anabatic and katabatic winds, inversions, frost pockets, and radiation fog

- evaluate the influence of local climates on human activities - settlement and farming
- explain reasons for differences between rural and urban climates
- explain the causes and effects of urban heat islands
- explain the causes and effects of pollution domes
- outline strategies to reduce the heat island effect

## **MID - LATITUDE CYCLONES**



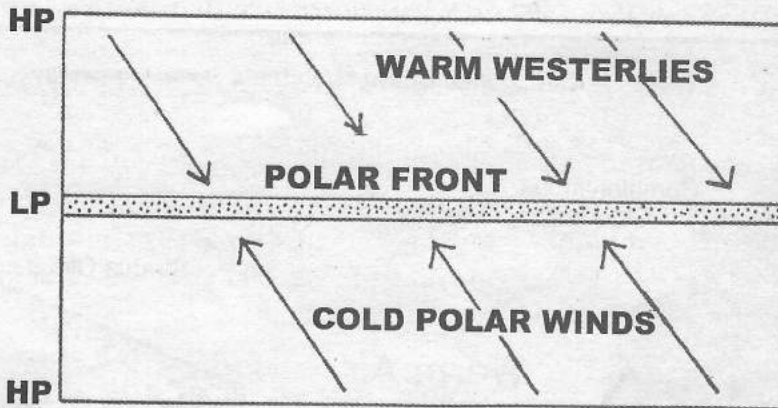
## **GENERAL CHARACTERISTICS OF MID - LATITUDE CYCLONES**

- Air circulates in a mid - latitude cyclone in the southern hemisphere in a **clockwise** direction.
- Air circulates in a mid - latitude cyclone in the northern hemisphere in an **anticlockwise** direction.
- Generally move from **west to east**.
- Occur in the **westerly wind belt**.
- Steered by the **westerlies**.
- Occur between **latitudes 30° N/S and 60° N/S**.
- Occur in **summer** and in **winter**.
- Present over **land** and **ocean**.
- Diameter may exceed **1000 kilometres**.
- Consist of a **warm air mass** and a **cold air mass**.
- Consist of a **warm front** and a **cold front**.
- Last for a **few days** up to a **week**.
- Sometimes occur in **groups** known as cyclone **families**.
- Also known as **temperate cyclones**, **extra - tropical cyclones**, **frontal depressions** and **wave cyclones**.

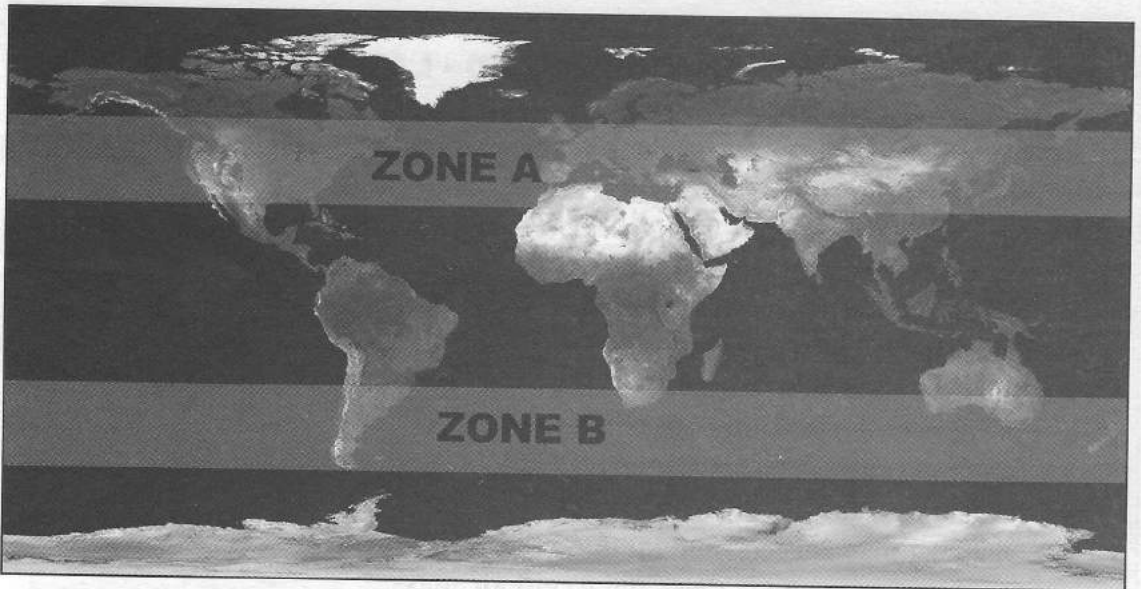
## AREAS WHERE MID - LATITUDE CYCLONES FORM

Mid - latitude cyclones occur in the **westerly wind belt** between latitudes  $30^{\circ}$  N/S and  $60^{\circ}$  N/S. They originate at the **polar front**. The polar front is a zone that separates the **warm westerlies** (tropical air mass) from the **cold polar winds** (polar air mass). The polar front is situated at the  $60^{\circ}$  N/S latitude.

*Note that a front is a zone of separation between warm and cold air. The sketch below illustrates the polar front in the southern hemisphere.*



The map below shows the approximate areas where mid - latitude cyclones occur. **Zone A** represents areas of development in the northern hemisphere and **Zone B** represents areas of development in the southern hemisphere.



## CONDITIONS NECESSARY FOR THE FORMATION OF MID - LATITUDE CYCLONES

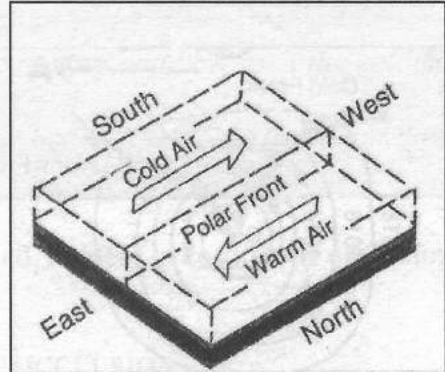
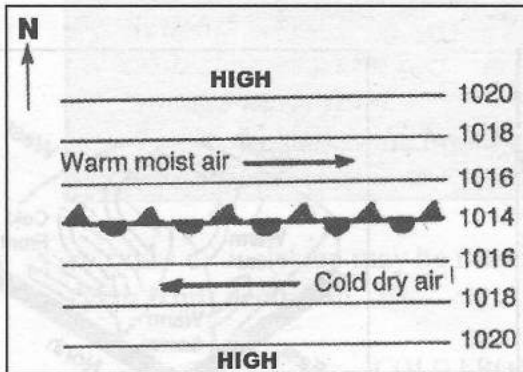
- area of development between  $30^{\circ}$  N/S and  $60^{\circ}$  N/S
- the convergence of cold polar winds and warm westerlies at the polar front

- there must be an **area of low pressure** around which winds circulate
- the **divergence of air** above the low pressure centre
- the **inflow of warm, moist air** at low and mid levels
- the **release of latent heat** caused by convection in the warm air mass sector

## STAGES IN THE DEVELOPMENT OF A MID-LATITUDE CYCLONE IN THE SOUTHERN HEMISPHERE

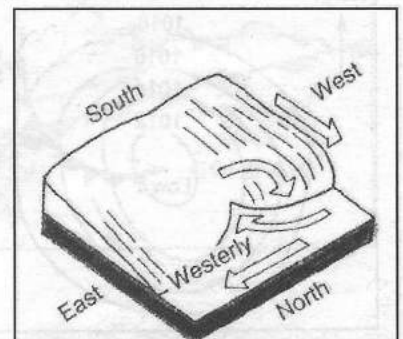
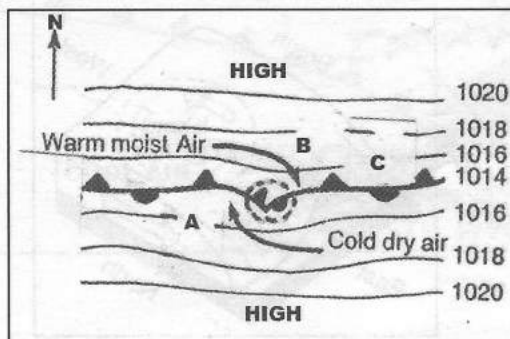
***Cyclogenesis: the origin and development of a cyclone.***

### 1. INITIAL STAGE



- This stage marks the **beginning** of a mid - latitude cyclone.
- During the initial stage the two air masses (warm moist air and cold dry air) are separated by the **polar front**.
- The polar front during this stage is a **stationary front**.
- The warm air mass and the cold air mass move **parallel** to each other in **opposite** directions.
- This air movement leads to **friction** along the polar front.
- As a result, the polar front which was straight now becomes **wave - like**. (Hence a mid - latitude cyclone is also referred to as a **wave cyclone**).

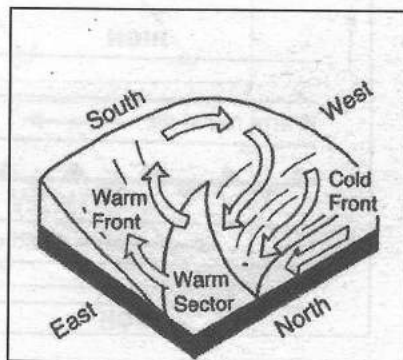
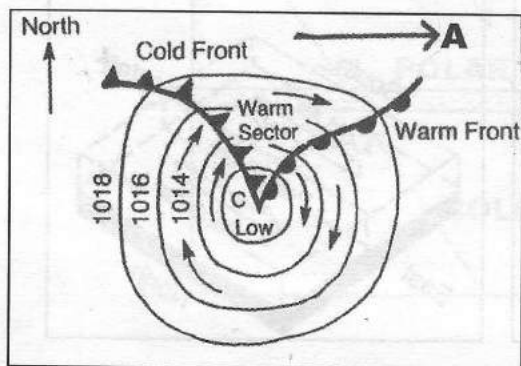
### 2. DEVELOPING STAGE



- During this stage the front becomes **wave - like**. (A **disturbance** has formed along the front).
- A low pressure centre forms at the **apex** of the wave.

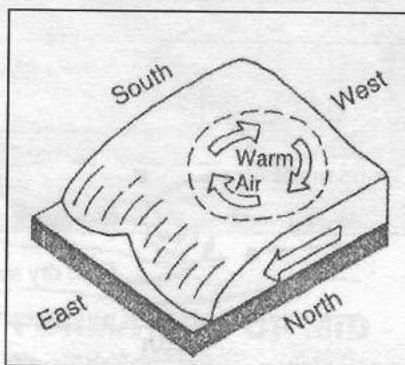
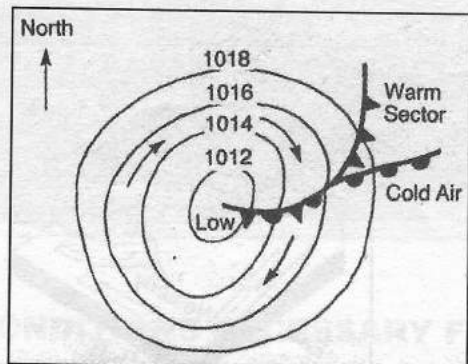
- The air circulates around the low pressure centre in a **clockwise** direction (southern hemisphere).
- The cold air **underrides** the warm air (A on the diagram). This results in the formation of a **cold front**.
- The warm air **overrides** the cold air (B on the diagram). This results in the formation of a **warm front**.
- Note that during this stage, the cold front and the warm front begin to develop. Further away from the apex of the cyclone, the front remains stationary (C on diagram).
- During this stage the cyclone is characterized by a **shallow wave**. The wave **deepens** as the cyclone develops further.

### 3. **MATURE STAGE**



- During the mature stage the wave has **deepened** or intensified.
- The time interval from the origin of the wave to the mature stage is approximately 12 hours.
- The arrow labelled A in the sketch indicates the general direction in which a mid - latitude cyclone moves (west to east).
- The cold front, warm front, warm sector and cold sector are **fully developed** during this stage.
- This is the **most intense stage** in the development of a mid - latitude cyclone.

### 4. **OCCCLUSION STAGE**



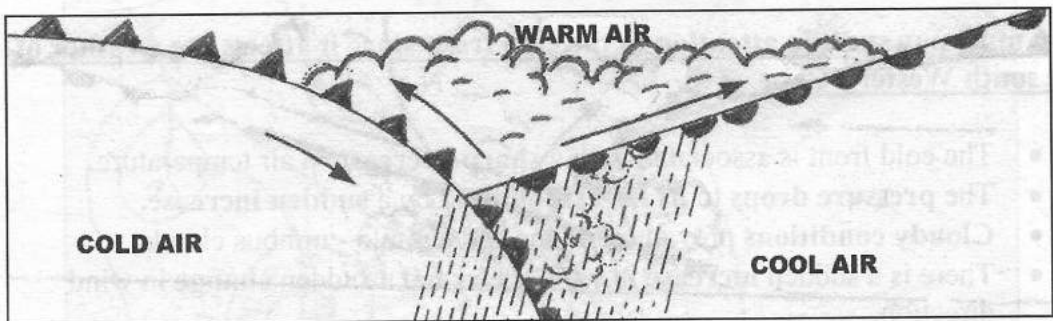
- The occlusion stage represents the **final stage** in the life - cycle of a mid - latitude cyclone.
- This stage is also referred to as the **dissipating or degenerating stage**.

- This stage is characterized by the presence of an **occluded front**.
- **An occluded front forms in the following way:** As the mid-latitude cyclone moves, the cold front and the warm front also move. Since the air in circulation behind the cold front is dense, the cold front moves faster. As a result the cold front will eventually **catch up** with the warm front to form an occluded front. The process of occlusion begins at the **apex of the wave** since the distance between the cold front and the warm front is the **shortest** at this point. Gradually occlusion spreads in an upward direction until the entire front is occluded.

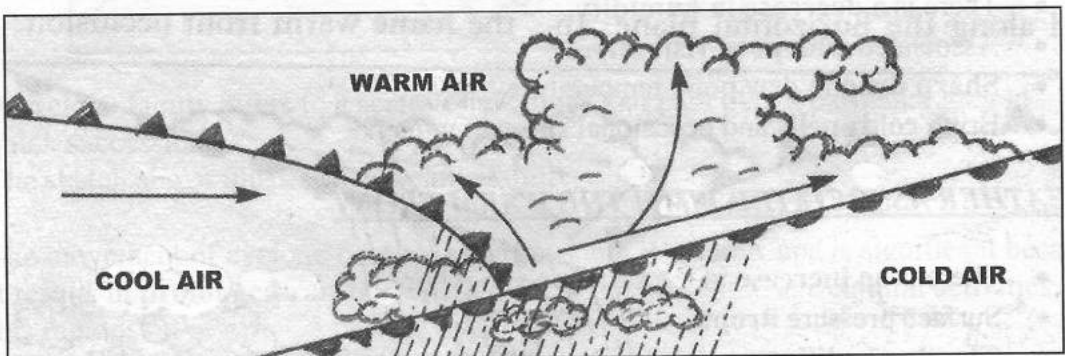
- *The cold front moves faster because the air in circulation behind it is dense.*
- *The warm front moves slowly because the air in circulation behind it is light.*
- *Note that the warm sector is the narrow zone between the cold front and the warm front.*
- *The cold sector is the broad zone between the cold front and the warm front.*

Two types of occlusion may be identified, namely, a **cold front occlusion** and a **warm front occlusion**.

#### COLD FRONT OCCLUSION



#### WARM FRONT OCCLUSION



## **Cold front occlusion**

In a cold front occlusion, the air in front of the warm front is warmer than the air behind the cold front. Note that the occluded front is an extension of the cold front line.

## **Warm front occlusion**

In a warm front occlusion, the air in front of the warm front is colder than the air behind the cold front. Note that the occluded front is an extension of the warm front line.

## **WEATHER PATTERNS ASSOCIATED WITH COLD, WARM, AND OCCLUDED FRONTS**

**“Different types of weather are associated with the different parts of a mid - latitude cyclone.”** You must be thoroughly familiar with the sequential weather changes that occur with the passage of a mid - latitude cyclone. This understanding will enable you to **predict** and **forecast** weather conditions.

### **WEATHER ASSOCIATED WITH THE COLD FRONT**

**You must pay specific attention to the cold front since it affects the weather of the south Western Cape.**

- The cold front is associated with a **sharp decrease** in air temperature.
- The **pressure drops** to its **lowest** followed by a **sudden increase**.
- **Cloudy conditions** prevail (cumulus and cumulo - nimbus clouds).
- There is a sudden **increase** in wind speed and a sudden **change** in wind direction.
- The cold front is sometimes associated with **thunderstorm activity** (torrential rain, hail, thunder, lightning and gusty winds).
- There is a **decrease in humidity**.
- Associated with **poor visibility**.
- **Sharp drop** in dew point temperature.
- Bring **cold spells** and occasional **snow** in winter.

### **WEATHER ASSOCIATED WITH THE WARM FRONT**

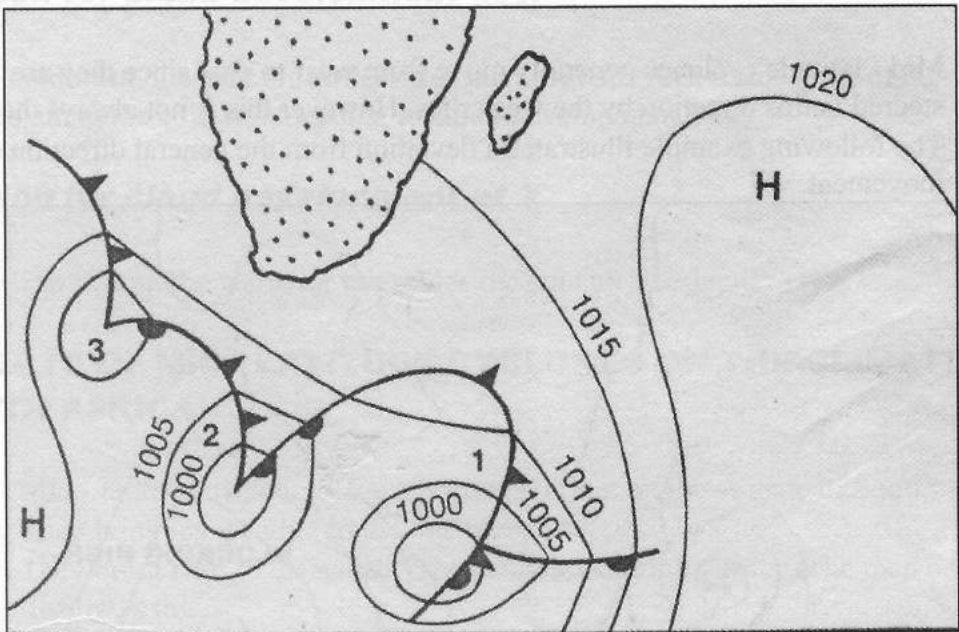
- There is an **increase** in the surface temperature.
- Surface pressure **drops**.
- **Cloudy conditions** prevail (cirrus, cirrostratus and nimbostratus clouds).
- At first there is **light rain**, later followed by **heavy showers**.
- There is a sudden **increase** in wind speed and a sudden **change** in wind direction. Winds are **variable**.
- Visibility is **poor**.
- **Fog** can precede the passage of a warm front.

- Steady **rise** in dew point temperature.
- **Increase in humidity.**
- Warm fronts are associated with a **frontal inversion**. Temperature increases with height along the frontal line.

### WEATHER ASSOCIATED WITH THE OCCLUDED FRONT

- There is a possibility of **thunderstorms**.
- Air mass begins to **dry**.
- Wind **changes direction** as the front passes.
- Cold front occlusion is associated with a **drop in temperature**.
- Warm front occlusion is associated with an **increase in temperature**.
- **Light, moderate or heavy continuous precipitation** occurs.
- Visibility is **poor** during precipitation.
- Associated with **cumulonimbus** or **nimbostratus** clouds.

### **CYCLONE FAMILIES**



A cyclone family refers to a **series of cyclones** that pass over a particular area in quick succession.

The sketch above illustrates a cyclone family.

The movement of cyclone families over the south Western Cape is significant because it results in **prolonged rainfall** which is highly beneficial to agricultural activities in this region.

Which of the cyclones numbered 1, 2 and 3 developed first? Explain your answer. Identify the stage of development of each of the cyclones numbered 1, 2 and 3.

## REASON FOR WARM FRONT NOT AFFECTING THE CLIMATE OF S. AFRICA

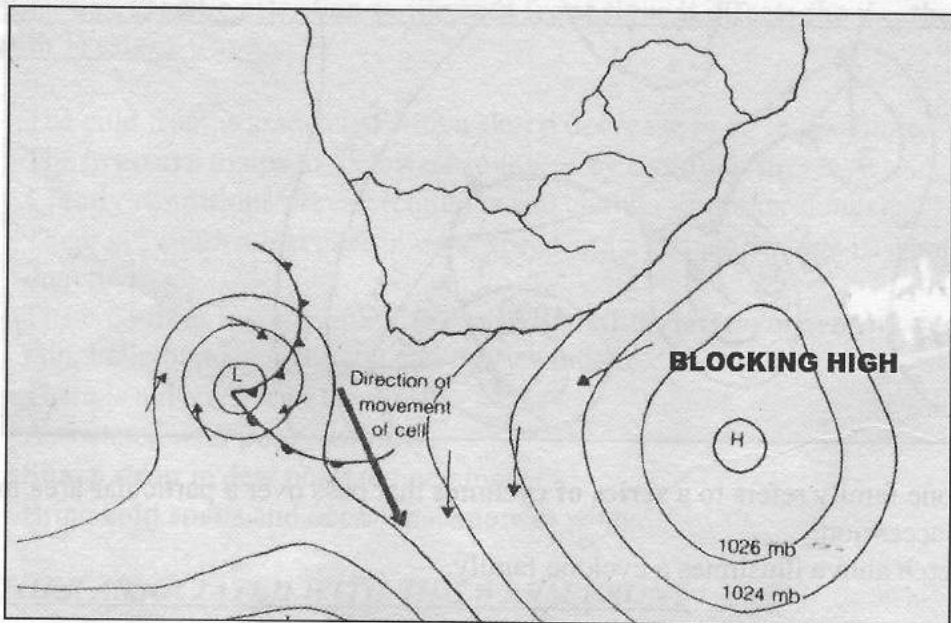
The warm front seldom passes over South Africa because the mid - latitude cyclone originates **too far south**. You must be able to explain this in detail with reference to the migration of the pressure zones.

## PASSAGE OF COLD FRONTS OVER SOUTH AFRICA

- The cold front of the mid - latitude cyclone passes over the south Western Cape in **winter** because the cyclone originates further north somewhere to the west of Cape Town. As a result of its eastward movement from its point of origin, it affects the climatic pattern of the south Western Cape.
- The cold front does not pass over the south Western Cape during **summer** because it originates **too far south** somewhere to the south west of Cape Town.

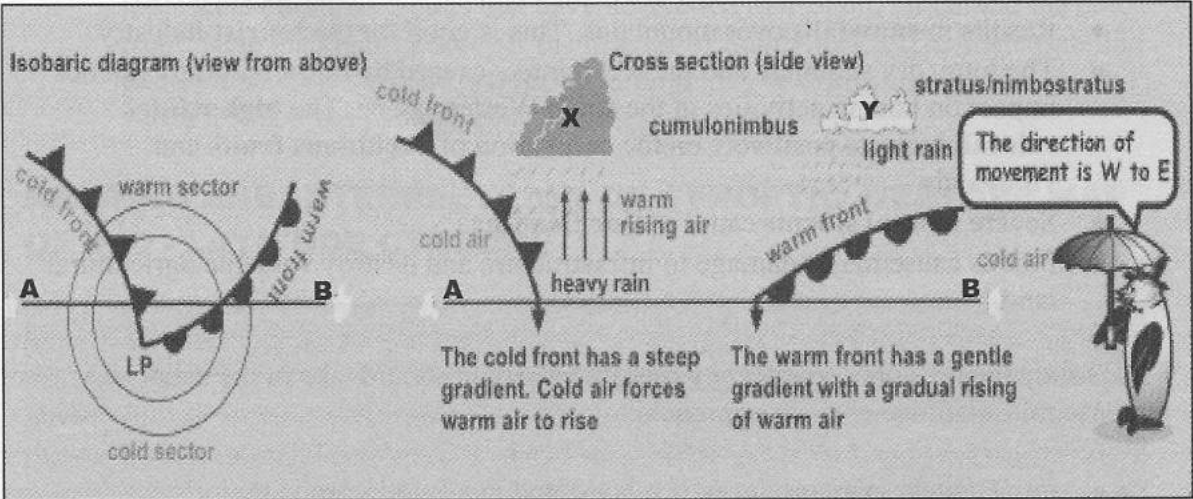
## PATH OF MID - LATITUDE CYCLONES

- Mid - latitude cyclones generally move from **west to east** since they are steered in this direction by the westerlies. However this is not always the case.
- The following example illustrates a deviation from the general direction of movement.



- In the above situation, the mid - latitude cyclone will not be able to move in an easterly direction because of an **anticyclone** that lies in its path. The cyclone will move in a **south easterly direction** in order to avoid the anticyclone. The anticyclone, therefore, is known as a “**blocking high**”.

# CROSS SECTION THROUGH A MATURE MID - LATITUDE CYCLONE SHOWING FRONTAL AND CLOUD DEVELOPMENT



## Reason for cloud development at X

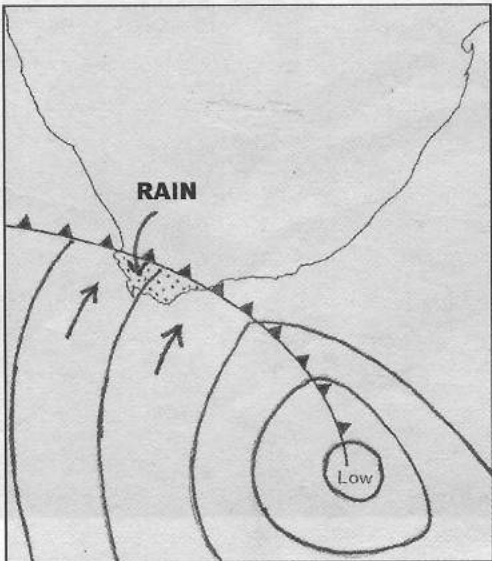
At the cold front, the cold air **underrides** the warm air. As a result some of the warm air rises along the cold front leading to cloud development.

## Reason for cloud development at Y

At the warm front, the warm air **overrides** the cold air causing it to rise.

## EFFECTS OF MID - LATITUDE CYCLONES ON THE CLIMATE OF SOUTH AFRICA

- Mid - latitude cyclones have a profound effect on the climate of South Africa.
- They bring icy weather to the interior.
- They bring **rain** to the **south Western Cape** during **winter**. The map below illustrates this.



## IMPACT OF MID - LATITUDE CYCLONES ON HUMAN ACTIVITIES IN SOUTH AFRICA

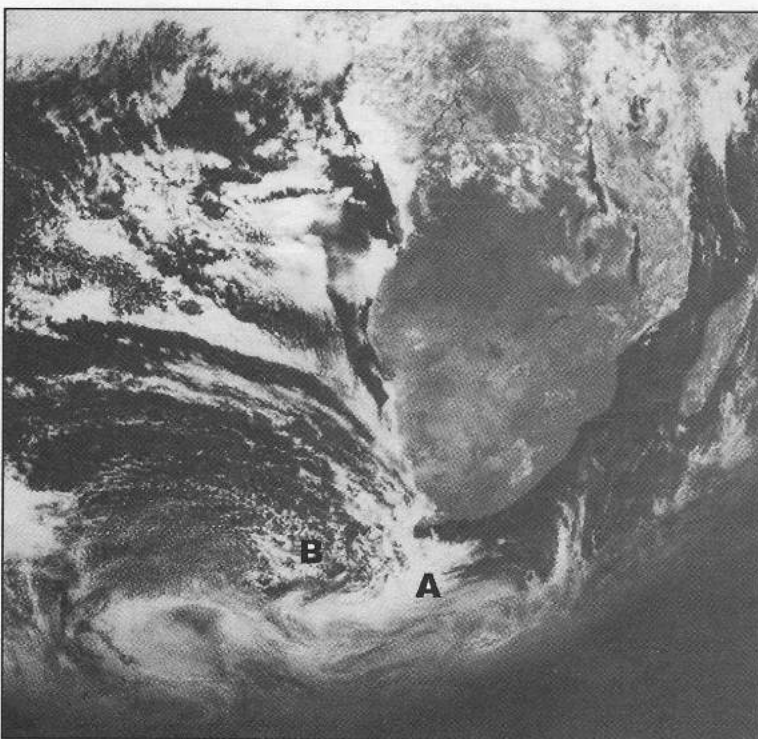
- Results in **snowfalls** over mountains. This is good for the **tourist** industry.
- The long, dry summers and the wet winters caused by mid - latitude cyclones impact on human activities in the south Western Cape. The **high winter rainfall** impacts positively on the cultivation of **deciduous fruits** and **vineyards**.
- Severe **frontal storms** cause **major flooding**.
- Floods cause major damage to infrastructure and destroy valuable agricultural land.

The following are some **emergency measures** people should take in the event of an intense mid - latitude cyclone approaching:

- immediately **evacuate area** if it is located in a flood - prone region
- place **sandbags** in the direction from which water may enter dwellings
- secure **warm clothing** especially for children
- **remain indoors**
- stock up on **food and medical supplies**
- have **candles, torches and lamps** at hand in case of power failure
- **fill up fuel** in vehicles
- **plan a line of emergency action** in consultation with local community members

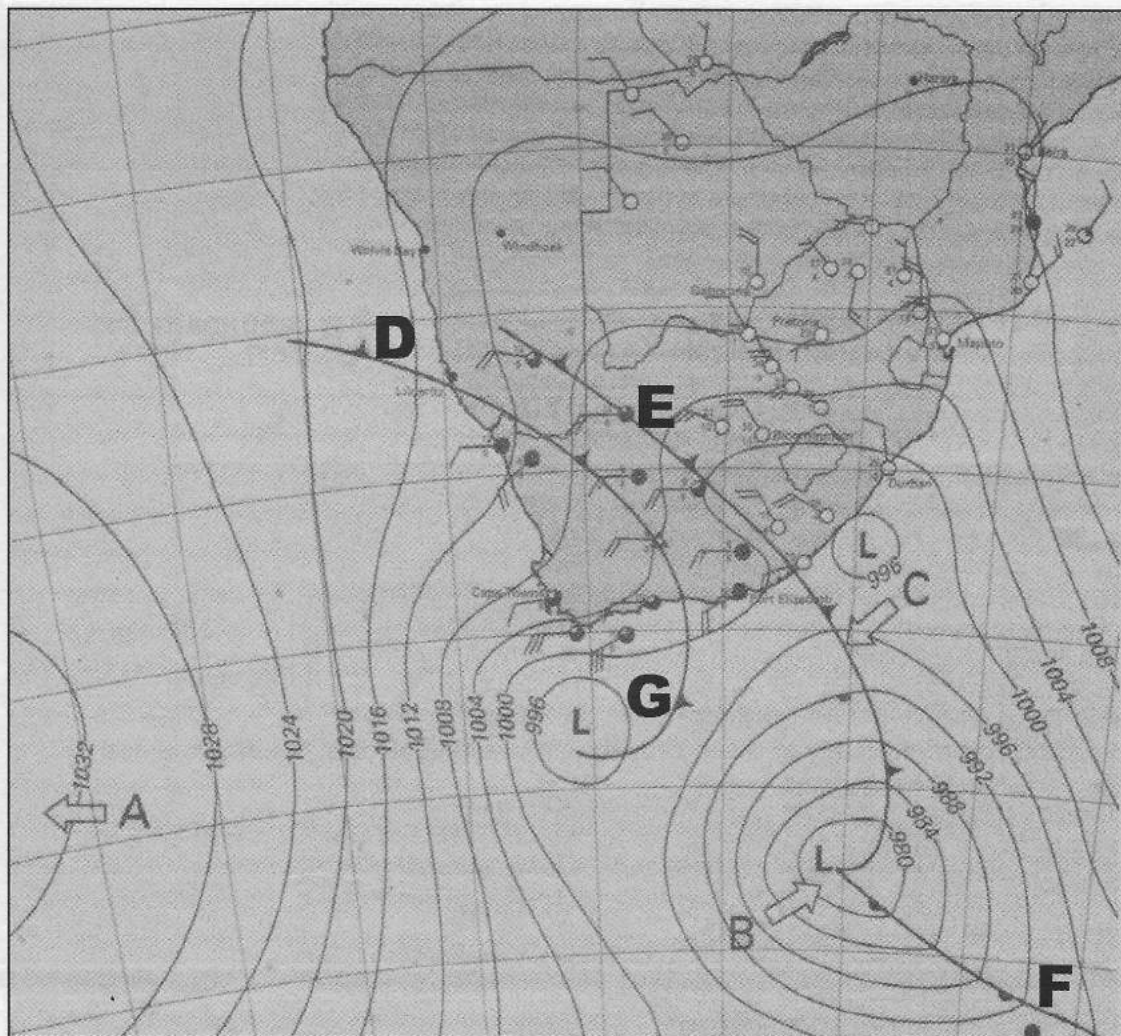
## READING AND INTERPRETATION OF SATELLITE IMAGE OF MID - LATITUDE CYCLONE

SATELLITE IMAGE OF MID - LATITUDE CYCLONE



- The above satellite image shows air movement and cloud development in a **mid - latitude cyclone** to the south west of South Africa. The bright band of cloud labelled A refers to cloud development in front of the cold front. B represents **cumulus** clouds that have developed in the cold air behind the cold front. Note the **clear skies** over the interior of South Africa. The meteosatellite photograph shows typical **winter** conditions. Try to draw in the cold front and warm front on the photograph.

## READING AND INTERPRETAION OF SYNOPTIC WEATHER MAP OF MID - LATITUDE CYCLONE



### ACTIVITY 1

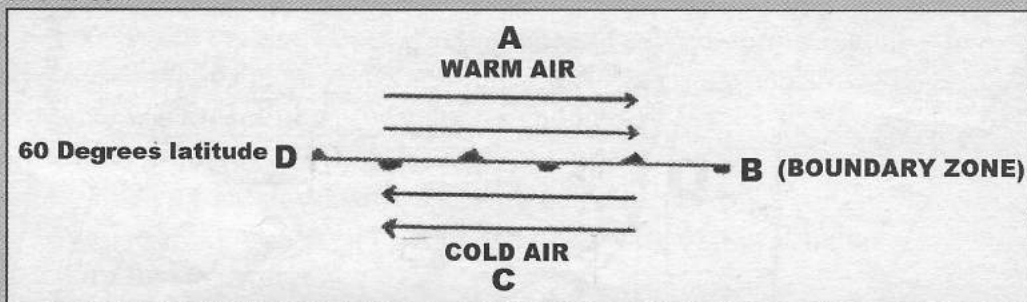
Refer to the synoptic weather map showing mid - latitude cyclones over South Africa and answer the following questions.

1. Identify the fronts labelled D, E and F.
2. Which of the mid - latitude cyclones labelled B or G originated first?
3. Give a reason for your answer to question 2.

4. Which of the mid - latitude cyclones B or G is more intensely developed?
5. Give a reason for your answer to question 4.
6. What is the general wind direction behind the front labelled E?
7. Give a reason for the wind direction referred to in question 6.
8. Explain how mid - latitude cyclones affect the weather of the south Western Cape.

## **ACTIVITY 2**

Refer to the sketch below showing air movement at the polar front and answer the questions set.



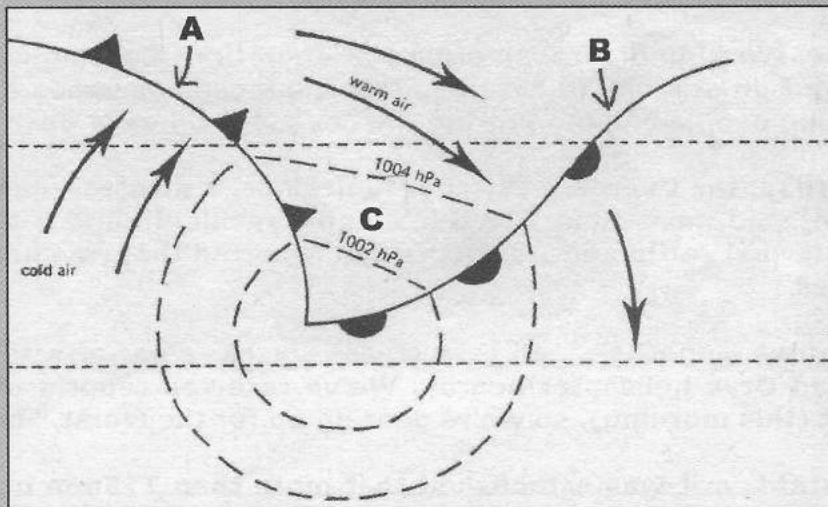
1. Identify the type of front represented.
2. Explain the concept "front".
3. In which direction does the air pressure increase: towards A, B, C or D?  
Give a reason for your answer.
4. State the hemisphere in which the above weather conditions occur.  
Give a reason for your answer.
5. State whether the above weather condition is typical of a temperate or a tropical cyclone.  
Give a reason for your answer.
6. What stage in the development of a mid-latitude cyclone is shown in the sketch?

## **ACTIVITY 3**

Study the sketch showing one of the stages in the development of a cyclone.

1. Explain the term cyclogenesis.
2. Identify the type of cyclone represented.
3. Identify the phenomena labelled A, B and C.
4. Does the sketch represent a northern or southern hemisphere cyclone?  
Give a reason for your answer.
5. Account for the air circulation within the system.

6. State the general direction in which this cyclone moves.  
Give a reason for this.
7. Where does this type of cyclone originate?
8. Identify the stage of cyclone formation represented in the sketch.  
Give **two** reasons for your answer.
9. State the stage of cyclone formation following the stage represented in the sketch.
10. Explain the process of air movement taking place at the warm front.
11. Explain the process of air movement taking place at the cold front.
12. State **three** conditions that are necessary for the formation of the cyclone represented.
13. Give **three** other names for the cyclone represented.
14. Explain why the cyclone represented does not affect the climate of the south Western Cape in summer.
15. State the stage of cyclone formation preceding the stage represented in the sketch.
16. Explain how the weather system represented affects agricultural activities in the south Western Cape.



#### **ACTIVITY 4**

Work through the following activity on your own and submit to your teacher for assessment. Study the extract taken from the Mercury.

**‘WORST IS YET TO COME’**

# Flooding set to continue in the Cape

More than 200 homes in the Overberg area have been damaged by yesterday's torrential rain, and scores of residents have been evacuated - but disaster management fears "the worst is yet to come".

This comes in the wake of fresh warnings by the South African Weather Service that the stormy conditions are expected to continue today with a high risk of more flash floods and the severe weather expected to spread inland.

Hermanus, Greyton, Genadendal, Caledon, Riviersonderend and Stanford were among the harder - hit towns and villages.

According to the South African Weather Service's KwaZulu - Natal office, there is no extreme weather expected for KwaZulu - Natal in the next couple of days, just scattered showers and thunderstorms, continuing until the weekend.

In the Cape, Working of Fire, an organisation of fire - fighting volunteers, has been put on standby in case disaster management needs assistance in evacuating people and monitoring the "hectic and heavy flash floods".

Late yesterday, the Overberg District Municipality's disaster management spokesman, said more than 100 Genadendal residents and a number of Caledon informal settlement residents had reported that rain had flooded their houses.

"In Hermanus, another 115 structures were also affected. We've stationed an Oryx helicopter nearby. We've received reports of another front to hit (this morning), so we're gearing up for the worst," he said.

Earlier yesterday, it was established that more than 115mm of rain had fallen in Caledon in a few hours and at least 25mm had fallen every hour.

"It's raining harder and harder by the minute. It started about midnight and hasn't stopped. Four families in Caledon have also been evacuated."

The R43 between Stanford and Hermanus, the road between Boskloof and Spanjaardskloof as well as the R406 between Greyton and Riviersonderend had to be closed because of flooding. Roads between Caledon and Genadendal, the N2 between Swellendam and Riviersonderend and a gravel road to Malgas were also flooded. Claude Schroeder, the Eden District Municipality's Acting Municipal Manager, said heavy rains had led to 15 homes in the Heidelberg area being flooded and one family had to be evacuated.

"It's still raining. The Slangrivier and Riversdale areas were badly affected. We've given the residents whose homes were flooded blankets and they'll stay in their homes. The situation is under control, but because it's still raining we don't know what can be expected," he said.

Schroeder said more than 100mm of rain was expected to fall today and tomorrow. "Very rough seas" were also expected with swells of more than 5m between Cape Point and Plettenberg Bay.

Johan Minnie, the City of Cape Town's disaster management spokesman, said even though it was raining hard, no flooding reports were received from in and around the city yesterday.

The SA Weather Services warned heavy rainfalls that could lead to flash flooding were expected in the Overberg, Breede River Valley and Eden District Municipality and were likely to continue today.

1. In which province is Cape Town located? [2]
2. Name the weather system that is responsible for these floods. [2]
3. During which season do these floods generally occur in the Cape? [2]
4. Explain the reason for this (answer 3). [6]
5. Draw a diagram to illustrate this weather system (answer 2) in its mature stage. Label your diagram fully. [8]
6. Identify the primary disaster management strategy that was adopted to cope with the flood. [2]
7. What is a flash flood? [2]
8. Why does disaster management fear that "the worst is yet to come"? [4]
9. Suppose you are a member of the Disaster Management Team, what aid would you ensure is provided to people that have been evacuated. [6]
10. Why were "very rough seas" experienced? [2]
11. Name two other forms of extreme weather conditions. [4]

**TOTAL MARKS: 40**

## **ACTIVITY 5**

Refer to the satellite image below, showing the position of an approaching low - pressure system west of South Africa; and read the accompanying weather forecast before answering the questions that follow.

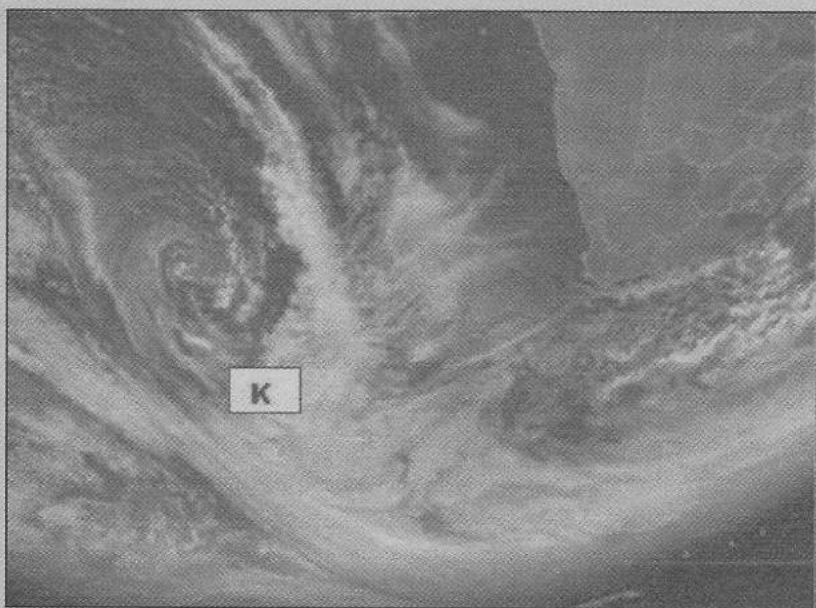
### **KEEP YOUR WINTER WOOLIES OUT** (Tuesday, 1 July 2008)

**Nice clear skies with cool temperatures can be expected for Tuesday and Wednesday, but people in the Western Cape need to brace themselves for another few cold, wet and windy days from Thursday the 3<sup>rd</sup> of July 2008.**

**The South African Weather Service has been issuing**

advisories for this approaching system since the beginning of the week. On Thursday gale - force northerly to northwesterly winds are expected between Cape Columbine and Cape Agulhas, accompanied by very rough seas, with wave heights in excess of 5 m. Very cold conditions over the western interior of the Western and Northern Cape, spreading to the northern interior of the Eastern Cape and southern Free State, can be expected.

The colder conditions are expected to reach the north - eastern parts of the country on Saturday, with temperatures falling into the cold category. Isolated heavy falls of rain, which could lead to localized flooding, are expected over the Peninsula, Boland and Overberg areas on Thursday and Friday. The South African Weather Service appeals to the public to forward to them any reports or confirmation of significant weather events such as snowfalls, hailstorms, heavy rain, damaging winds etc. when they are observed. Such information can also be used for further research, which will contribute to the improvement of weather predictions for that particular area.

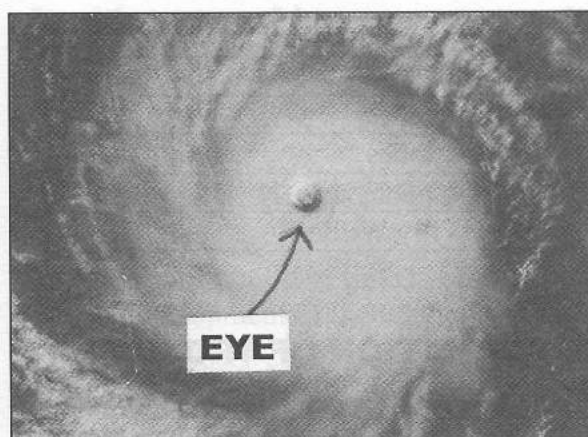


Satellite image showing the approaching low - pressure system on Monday the 30<sup>th</sup> June 2008 (image courtesy Eumetsat, 2008.)

1. Identify the low pressure system labelled K on the satellite image.
2. During which season does the above - mentioned low pressure system usually affect the weather of South Africa?
3. Give the general direction of the movement of the low pressure system mentioned in 1.

4. Give **one** reason for the direction of the movement of the low pressure system as mentioned in 3.
5. Draw a sketch map of the low pressure system in the satellite image above indicating its position in relation to South Africa.
6. Why is it important for the South African Weather Service to issue weather warnings?

## **TROPICAL CYCLONES**

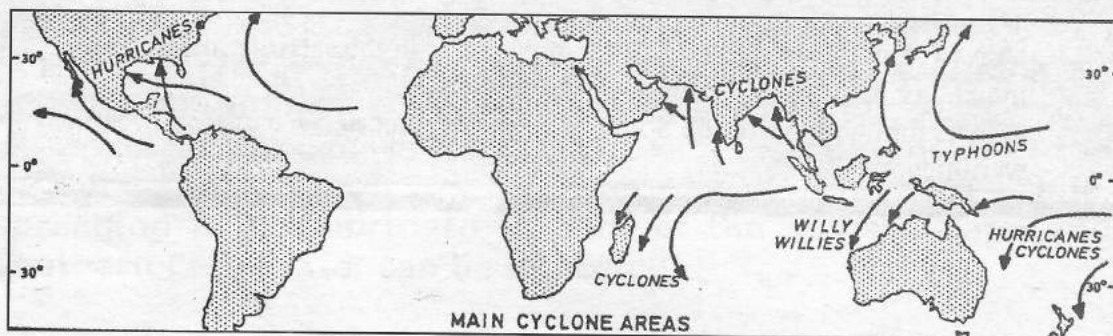


Tropical cyclones are intense low pressure systems. Tropical cyclones are **named** for the purpose of **identification** on the international register. The name of the first cyclone that occurs in a particular area will start with the letter A. In the above sketch cyclone **Barbara** is the **second** cyclone that occurred.

## **GENERAL CHARACTERISTICS OF TROPICAL CYCLONES**

- Generally move from **east to west**.
- Steered by the **easterlies**.
- Occur between latitudes **5° N/S** and **30° N/S**.
- Occur in the **trade** or **easterly wind belt**.
- Occur in **summer** only.
- Consist of **one air mass** only, namely, a **warm air mass**.
- Do not have **fronts**.
- **Dissipate** over **land**.
- Last for **three to five days**.
- **Diameter** is about **500 kilometres**
- The **centre** is known as the **"eye"**.
- They are also known as **cyclones**, **willy willies**, **hurricanes** and **typhoons**.

## AREAS WHERE TROPICAL CYCLONES OCCUR



AREAS OF OCCURRENCE	LOCAL NAME
1. Eastern USA and Gulf of Mexico	Hurricanes
2. Madagascar and Mauritius	Cyclones
3. Around India	Cyclones
4. China and Sea of Japan	Typhoons
5. Australia	“Willy Willies”

## FACTORS NECESSARY FOR THE FORMATION OF TROPICAL CYCLONES

### Area of development between 5° N/S and 30° N/S latitude

- They do not occur within 5 degrees of the equator because the **coriolis force** (CF) is very **weak**. The CF is essential for developing the **vorticity** of the cyclone.
- Within this latitudinal zone the **temperature** is **high**. Heat is essential for **convection**.
- Within this zone the **pressure** is **low** - cyclones cannot develop in anticyclonic conditions.

### A warm, extensive ocean surface. Surface temperature must be above 27° C.

- The **temperature** is **high** over a **warm ocean**. Heat is essential for **convection**.
- Over a warm ocean the **pressure** is **low**. Cyclones cannot develop in areas of high pressure.
- Over a warm ocean there is **sufficient moisture** which is essential for **condensation** and the **release of latent heat**.
- There is very **little friction** over the ocean.

## **Winds must be light and variable**

- If the wind is strong and blows from a constant direction, it will decrease the temperature over the ocean. This will **interfere with convection**.
- Strong winds blowing from a constant direction will also reduce the amount of moisture over the ocean. This will **interfere with condensation** and the release of latent heat.

## **Atmospheric instability**

- The air must be **unstable** so that **convection** can occur.

## **A wide area of low pressure with some closed isobars**

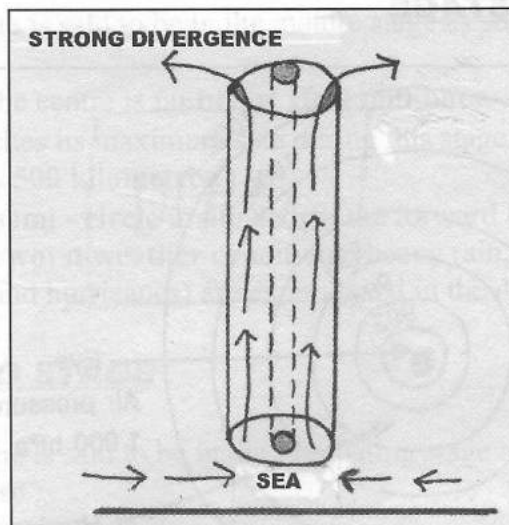
- Cyclones cannot form in areas of high pressure.

## **An undisturbed period of several days**

- A long period of time is essential for the **slow convergence** of air and the development of the **vorticity** of the cyclone.

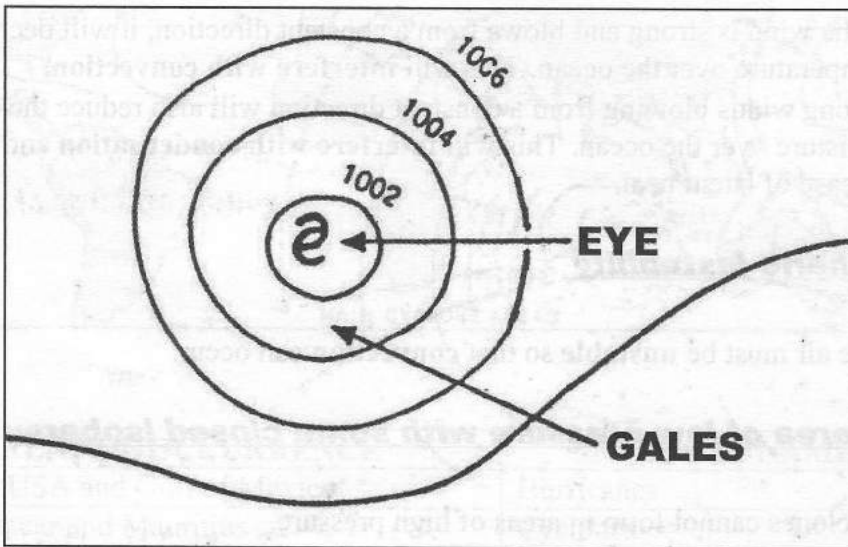
## **Some upper air triggering action**

- There must be **strong divergence** in the upper atmosphere. This creates a suction force allowing more moisture to be fed into the cyclone. The sketch below illustrates this process.



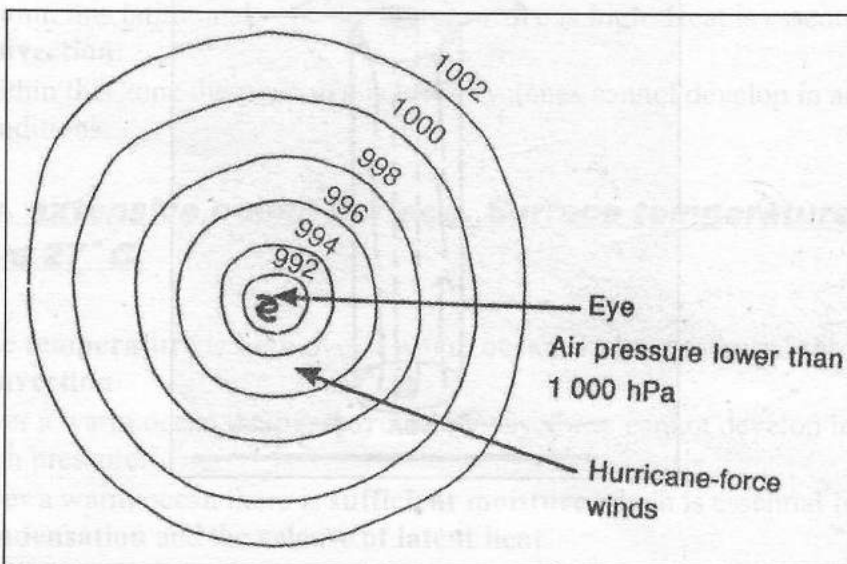
## **STAGES IN THE DEVELOPMENT OF A TROPICAL CYCLONE IN THE SOUTHERN HEMISPHERE**

## 1. FORMATIVE STAGE



- This stage is called the formative stage because the cyclone **begins to develop** during this stage.
- The “eye” also begins to form during this stage.
- Towards the centre of the cyclone the isobars are **circular** in shape and **closed**.
- Further away from the centre, the isobars remain **open**
- During this stage the air pressure **decreases** but the pressure at the centre is still **above** 1000 millibars.
- Surface air **rises** near the centre of the cyclone.
- **Gale force winds** occur about 50 kilometres from the eye.
- As the pressure drops further, the tropical cyclone becomes better developed.

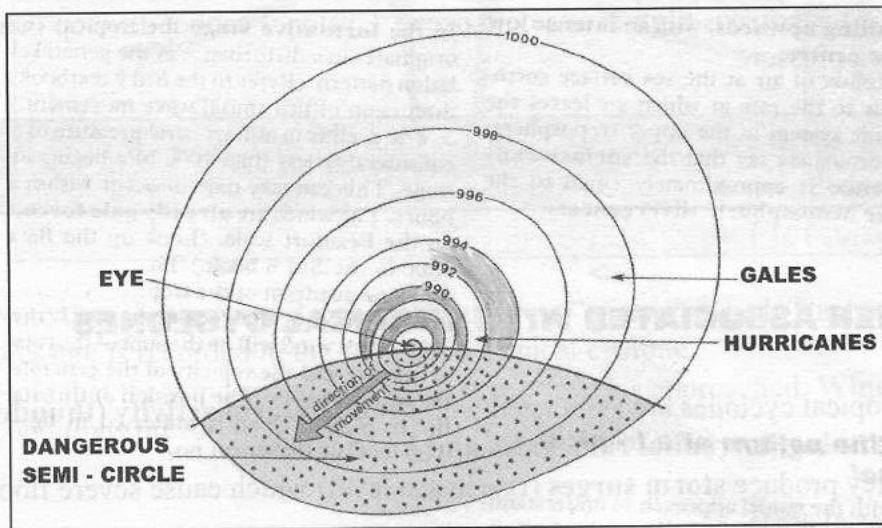
## 2. IMMATURE STAGE



- A tropical cyclone is said to be in the immature stage as soon as the **pressure** in the “eye” **drops** to below **1000 millibars**.
- The “eye” **intensifies** during this stage.
- Wind velocity **increases** during this stage (winds reach hurricane strength).

- **Air pressure** continues to **decrease** throughout this stage.
- The tropical cyclone attains a **diameter** of approximately **100 kilometres** during this stage.
- **Surface air** moving towards the low pressure centre **rises**. As a result of this air movement, the “eye” contracts causing the pressure to decrease even further.
- **Low level air** is significant in the development of the cyclone because it feeds the cyclone with **moisture** which is essential for **condensation** and the **release of latent heat**.
- **Clouds** form **around the “eye”** of the tropical cyclone. These towering clouds are known as **cumulo - nimbus** clouds.

### 3. **MATURE STAGE**



- A tropical cyclone is said to be in the mature stage as soon as the pressure **ceases to drop**.
- The pressure at the centre is far **below 1000 millibars**.
- The cyclone reaches its maximum size during this stage. It attains a **diameter** of approximately **500 kilometres**.
- The **dangerous semi - circle** is situated on the forward left hand quadrant of the cyclone. The **worst weather** conditions (heavy rain, hail, thunder, lightning, gales and hurricanes) are experienced in the dangerous semi - circle.

### 4. **DISSIPATING STAGE**

- A tropical cyclone is said to be in the dissipating stage as soon as the **pressure** begins to **increase**.
- The **area** covered by the cyclone **decreases**.

## REASONS FOR DISSIPATION OF TROPICAL CYCLONES

### Tropical cyclones dissipate over land because:

- Over land there is **friction** which interferes with the **vorticity** of the cyclone.
- There is **less moisture** over land. This interferes with **condensation** and the **release of latent heat**.

### Tropical cyclones dissipate over cold oceans because:

- The **temperature** over a cold ocean is **low**. This interferes with **convection**.
- There is **less moisture** over a cold ocean. This interferes with **condensation** and the **release of latent heat**.
- The **pressure** is **high** over a cold ocean. Cyclones cannot develop in areas of high pressure.

**make landfall** - the term used to describe the arrival of the eye of a tropical cyclone over the coast.

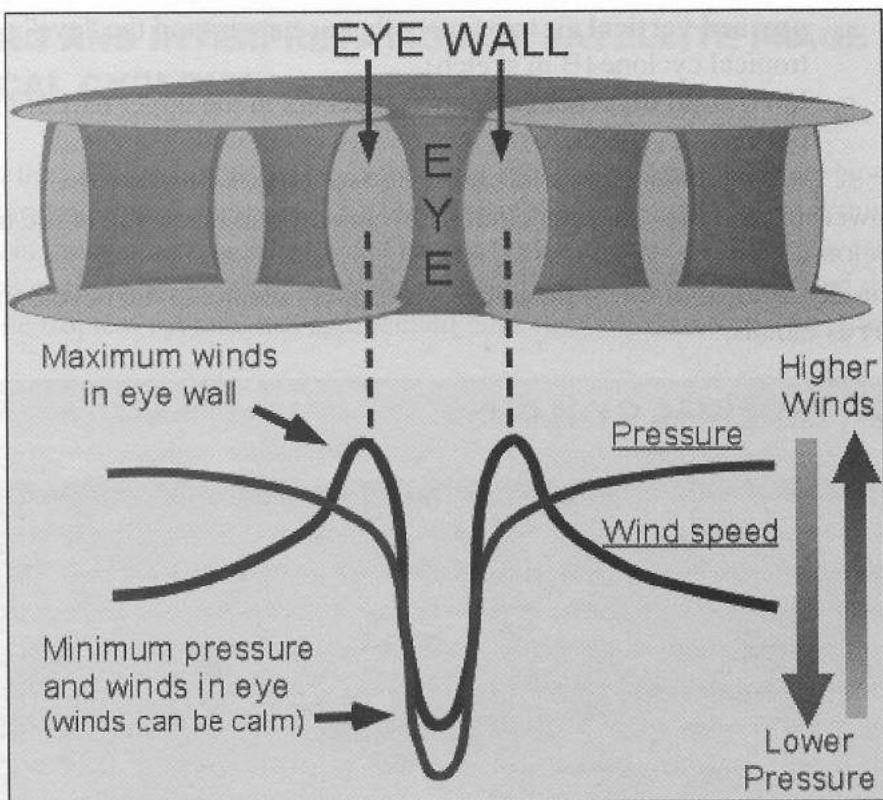
## **WEATHER ASSOCIATED WITH TROPICAL CYCLONES**

- Tropical cyclones are associated with **thunderstorm activity (thunder, lightning, torrential rain, gales and hurricanes)**.
- They produce **storm surges** (rise in sea level) which cause severe flooding in coastal areas.
- They cause **flash floods**.
- Associated with **cumulo-nimbus clouds**.
- The **eye** of the cyclone is associated with **calm weather**. It experiences **rainless, windless and cloudless** conditions).

## **REASONS FOR CALM WEATHER IN THE EYE (FORMATION OF THE EYE)**

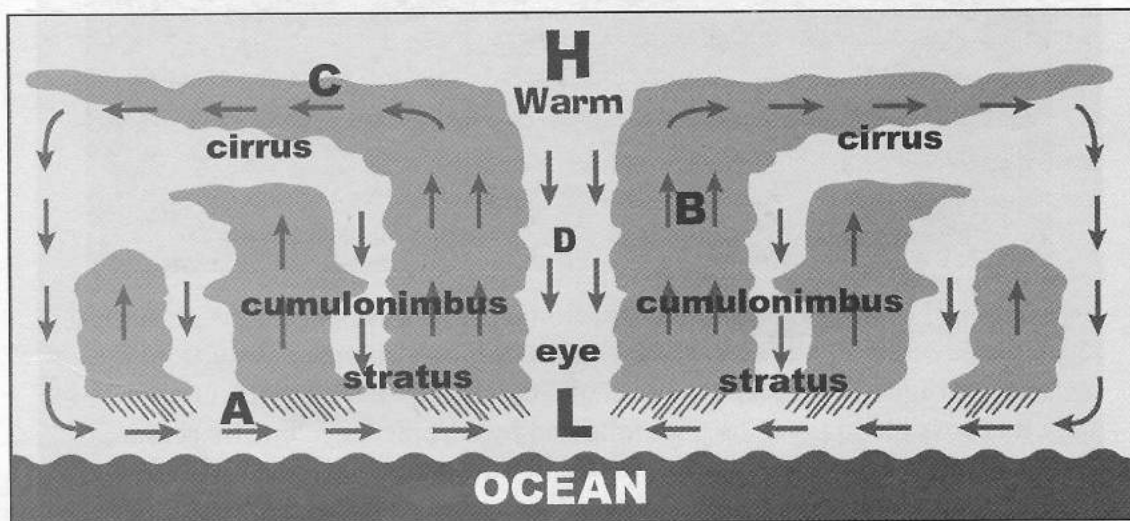
- The **upward spiraling** movement of air creates an **artificial wall** around the centre. This prevents surface air from rising. Hence there is no condensation and cloud development in the “eye”.
- The “**chimney**” is associated with the **subsidence** of air. The subsiding air also prevents the surface air from rising.

## **GRAPH SHOWING AIR PRESSURE AND WIND CONDITIONS ALONG THE PATH OF A TROPICAL CYCLONE**



- Note that air **pressure decreases** as the “eye” is approached. The lowest air pressure is recorded in the “eye” of a tropical cyclone.
- Note that the wind **speed increases** at the “eye” is approached. **Windless** conditions prevail in the “eye” of the tropical cyclone.

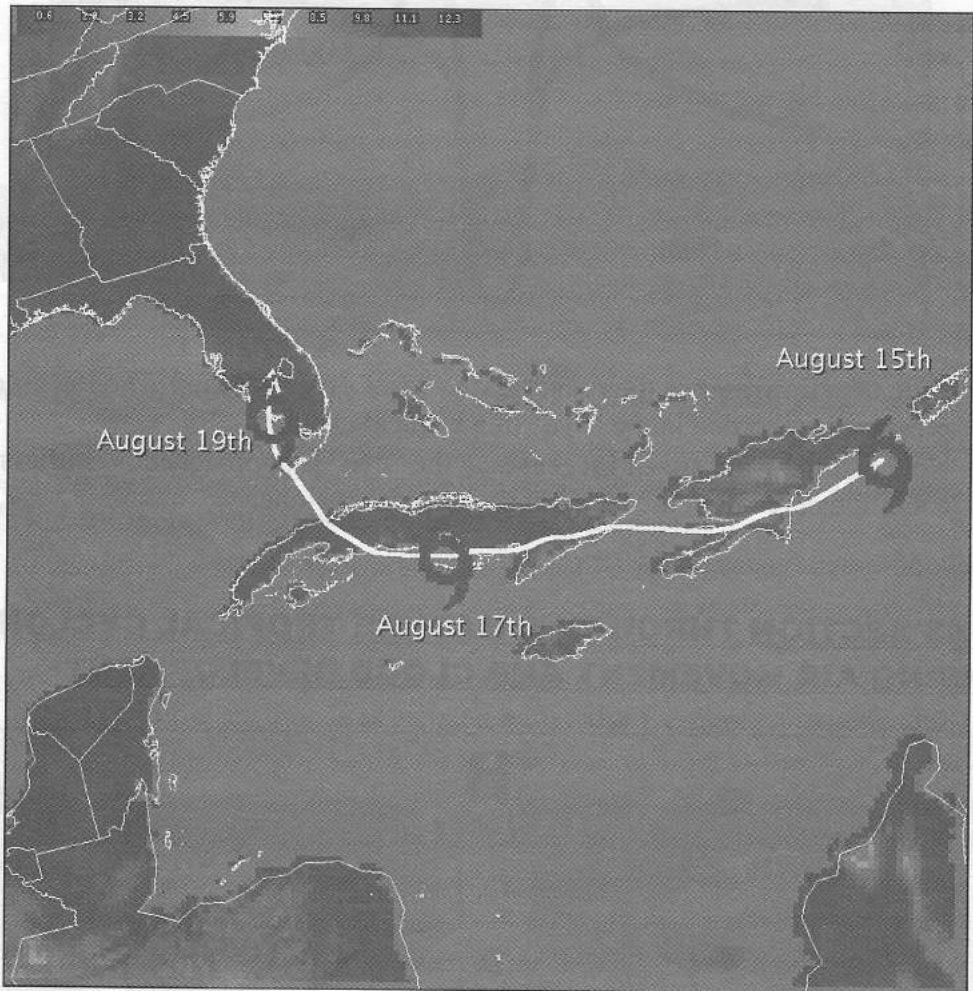
### **CROSS SECTION THROUGH A MATURE TROPICAL CYCLONE** **SHOWING AIR MOVEMENT AND CLOUD DEVELOPMENT**



- The sketch above shows **four** types of air movement associated with a tropical cyclone:
  - **surface (horizontal)** air movement that occurs above the warm ocean surface (A in the sketch).

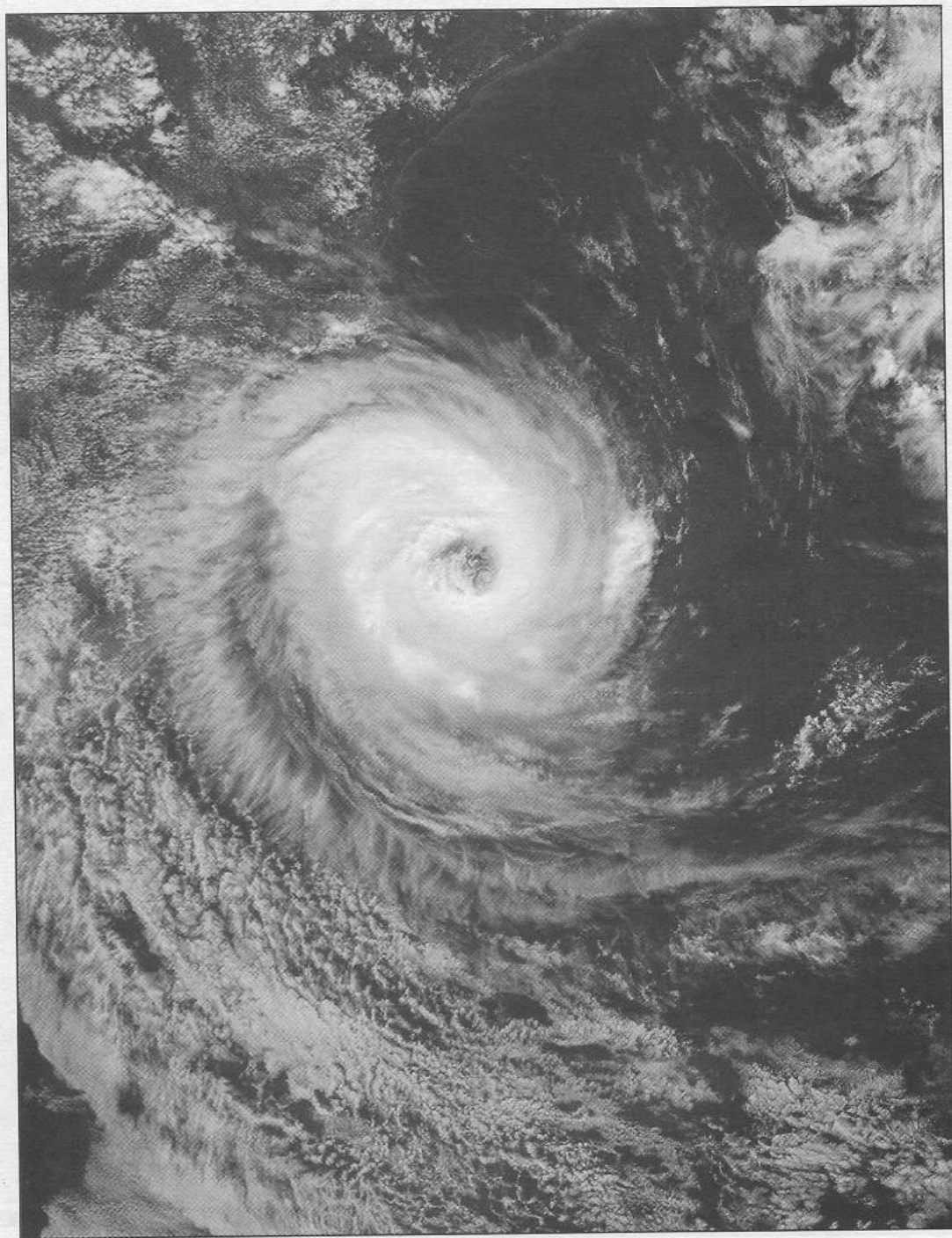
- **upward vertical** air movement that occurs around the “eye” of the tropical cyclone (B in sketch).
- **horizontal divergence** of air that occurs in the upper part of the cyclone (C in sketch).
- **subsidence** of air in the eye of the cyclone (D in sketch)
- Towering **cumulo - nimbus clouds** develop around the “eye” of the tropical cyclone.
- The **divergence of air** in the upper atmosphere results in the development of **cirrus** clouds.

## **PATH OF TROPICAL CYCLONES**

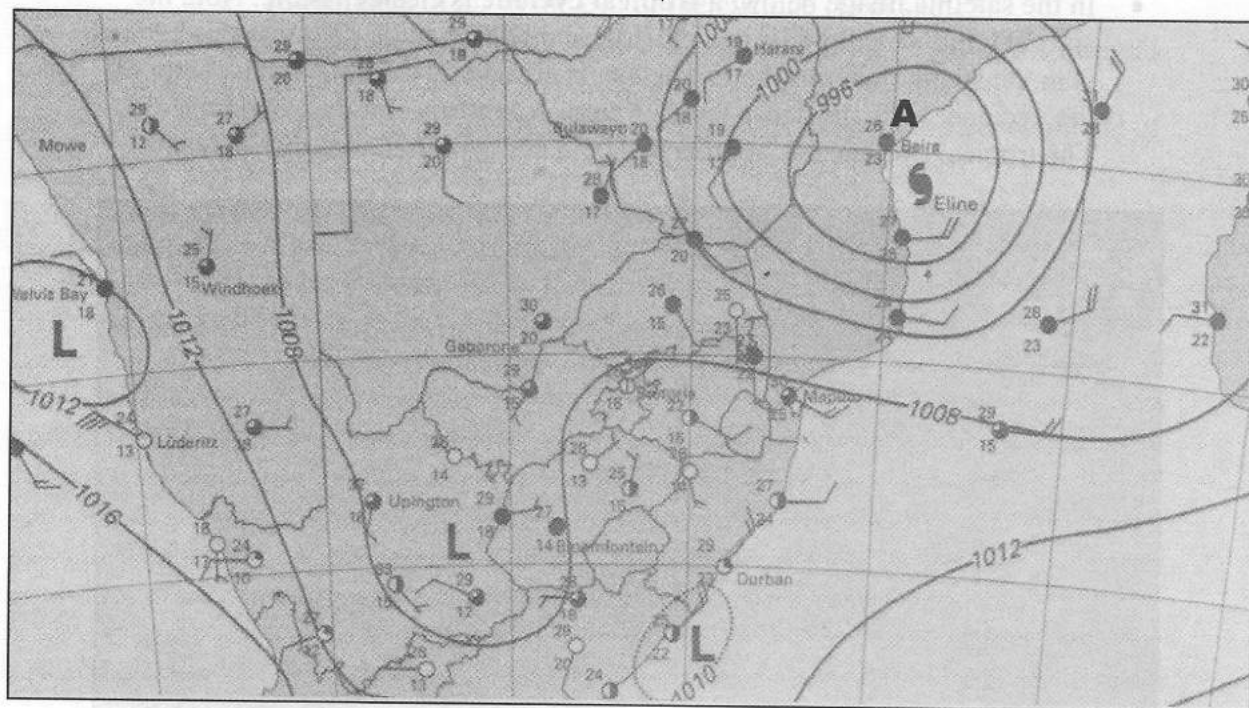


## READING AND INTERPRETATION OF SATELLITE IMAGE OF TROPICAL CYCLONE

- In the satellite image below, a **tropical cyclone** is clearly visible. Note the spiraling movement of air in a **clockwise** direction indicating that this cyclone is in the southern hemisphere. The **eye** is also clearly visible at the centre of the cyclone. Note the dense band of **cumulonimbus clouds** around the eye. The tropical cyclone has approached land and will therefore dissipate.



# READING AND INTERPRETATION OF SYNOPTIC WEATHER MAP OF TROPICAL CYCLONE



## ACTIVITY 6

Refer to the synoptic weather map above showing tropical cyclone Eline and answer the following questions.

1. Why are cyclones named?
2. How many tropical cyclones occurred in this area before cyclone Eline?
3. What is the centre of the tropical cyclone called?
4. Describe the air circulation within this cyclone. Give a reason for this.
5. Why do tropical cyclones such as Eline seldom affect the weather of South Africa?
6. Tropical cyclone Eline is likely to dissipate soon. Give **two** reasons for this.
7. What is the source of energy for this cyclone?
8. The frequency and intensity of tropical cyclones has increased in the recent past. What factor has been responsible for this?
9. Heavy rainfall is likely to occur at Beira (A on the map). Give **two** reasons to support this statement.

## **CASE STUDY OF ONE RECENT TROPICAL CYCLONE THAT AFFECTED SOUTHERN AFRICA**

### **ACTIVITY 7: CASE STUDY OF TROPICAL CYCLONE IRINA**

Answer the questions based on the information below.

Tropical cyclone Irina was a large tropical cyclone that brought gusty winds and torrential rain across Madagascar, Mozambique, and South Africa in late February and early March of 2012. Irina is considered one of the most devastating storms of the 2011 - 2012 season.

Irina originated in the Indian Ocean to the east of Madagascar and followed the track shown in the map below.



On 26 February 2012, Irina passed over northern Madagascar, bringing heavy rain. The system weakened as it passed over land.

Between 27 February and 1 March, the system was centered over the ocean close to the west coast of Madagascar. High rates of evaporation from the warm water ( $29^{\circ}\text{C}$ ) led to strengthening of the system.

Irina then moved westward, and by 3 March was only 280 km from the coast of Mozambique, but did not make landfall. Parts of Mozambique experienced strong winds (up to 92 km per hour), high rainfall and a drop in temperature.

As Irina moved south on 3 and 4 March, heavy rains were experienced over Swaziland and parts of KwaZulu - Natal.

From 5 March, Irina moved towards the open ocean, and by 6 March was no longer affecting weather over land. As Irina moved into cooler water, she began to lose strength.

On 9 March, Irina's winds dropped below 64, 8 km per hour and the storm began to dissipate.

The official death toll as of 6 March 2012 stood at 77. Five fishermen were killed off the Mozambique coast and at least three more people in the south of the country when a tree fell on their roof and collapsed. South Africa reported four fatalities as waves of up to three metres battered the port of Durban and forced all ships to seek safety. Irina is the deadliest storm of the season so far, and took the total death toll of the 2011 - 2012 season to 164. Several authorities along the western coast of Madagascar said that the storm destroyed nearly 1 348 homes and caused landslides which blocked several roads which isolated several villages.

#### EFFECTS OF TROPICAL STORM IRINA IN KWAZULU - NATAL



1. Why are tropical cyclones named?
2. How many tropical cyclones occurred in the area shown on the map before tropical cyclone Irina?
3. Describe the path followed by tropical cyclone Irina.
4. What was the duration of tropical cyclone Irina?
5. Why did the cyclone weaken over land?
6. Tropical cyclone Irina intensified along the west coast of Madagascar. Give two reasons for this.
7. Describe the weather conditions along the coast of Mozambique as the cyclone approached. (3 March).
8. "As Irina moved into cooler water, she began to lose strength". Give two reasons for this.
9. Why do tropical cyclones such as Irina seldom affect the weather of South Africa?
10. Give two reasons why trees fall during the onset of a tropical cyclone.
11. The port of Durban experienced a "storm surge". What is a storm surge?
12. Why do landslides occur during a tropical storm?
13. Why are satellite images of tropical cyclones important?

14. "Irina is considered one of the most devastating storms of the 2011 - 2012 season".

Give two pieces of evidence to support this statement.

## **IMPACT OF TROPICAL CYCLONES ON HUMAN ACTIVITIES AND THE ENVIRONMENT**

### **IMPACT ON HUMAN ACTIVITIES**

- Tropical cyclones bring **torrential rain** which is a relief to farmers especially after a drought.
- **Floods** impact **negatively** on farming. Subsistence farmers in the developing countries experience **food insecurity**.
- **Loss of livestock** caused by severe flooding and strong winds.
- People who depend on fishing for a livelihood suffer **food shortages** because of rough seas and storm surges.
- People may **lose their jobs** if they work in an industry that has been badly affected.
- When businesses are closed, **earnings will be lost**.
- **Destruction of crops** has a negative effect on exports.
- People suffer from **stress** due to loss of possessions and housing.
- There may be **looting** of properties - domestic and commercial.
- People might be **stranded** as a result of flooding - this will cause trauma.
- They **disrupt international shipping** and sometimes cause **shipwrecks**.

### **IMPACT ON THE ENVIRONMENT**

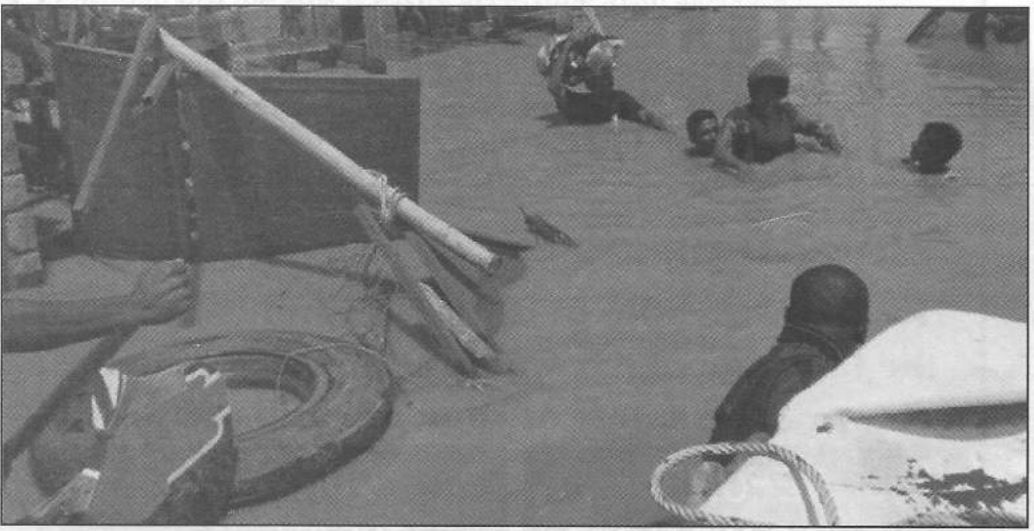
- Tropical cyclones cause **flooding** of low lying areas and the loss of thousands of lives.
- Hurricanes and gale force winds associated with tropical cyclones cause **shipwrecks**.
- Valuable **agricultural land** is **lost**.
- **Extensive damage** is caused to **property**.
- **Destruction of communication structures**.
- Cause **storm surges** (these are huge waves caused by the gales and hurricanes in the cyclone). Storm surges cause **extensive erosion** along the coast. Coastal dunes are washed away and the landscape is modified.
- Heavy rainfall causes **mudslides** and **landslides**.
- They play an important role in **energy balance** by transporting heat from the tropics towards the mid - latitudes and polar regions.
- They **damage or destroy motor vehicles, buildings, bridges, roads,** and other communication structures. This makes it difficult to transport food, clean water, and medicine to areas that need it.
- They **hurl loose debris** into the atmosphere.
- They **cut off power supply** to thousands of people.

- Cause extensive **damage to natural ecosystems**. **Food chains and food webs are disrupted**.
- **Fresh water supplies** may become **contaminated**.
- **Sewerage lines** may be cut resulting in a **lack of sanitation**, and the outbreak of **disease**.
- **Beaches** are often strewn with dead marine creatures and other debris.
- **Many coral reefs are damaged**.
- **Standing water** can cause the spread of **disease**.
- **Communities are displaced**. Many people are left **homeless**.

### **IMAGES OF IMPACT OF TROPICAL CYCLONES**

Comment briefly on each of the following images.





## **STRATEGIES THAT HELP TO PREPARE FOR AND MANAGE THE EFFECTS OF TROPICAL CYCLONES**

### **PRECAUTIONARY STRATEGIES**

The checklist below provided by the U.S. Department of Commerce: Weather Bureau provides useful information to safeguard yourself **before**, **during** and **after** the cyclone has passed. Study this information carefully.

# When a **HURRICANE**

**threatens...**



**Keep your radio or TV on . . . and listen to the latest advice from the Weather Bureau to ensure the safety of your life and property.**

## **BEFORE THE WIND AND FLOOD**



Fill the tank ...  
check battery and tyres

Build up a supply of drinking water. Collect food that does not require cooking or freezing.



Keep a torch, first-aid kit, fire extinguisher and a battery-operated radio handy.

Store all loose objects, toys, tools dirtbins, sun shades, etc. Board close all windows.



Evacuate all low-lying areas.

## **DURING THE STORM**



**STAY INDOORS . . .** Do not get misled when the calm "eye" moves right over you . . . and do not get caught outside when the hurricane winds restart from the OPPOSITE direction.



Listen to your radio or TV for information from the Weather Bureau, Community Protection, the Red Cross or any other institution.

## **AFTER THE STORM**



**STAY OFF THE ROADS**, unless it is a necessity. Beware of eroded pavements and damaged power lines.



Report damaged power lines, waterpipes or sewage pipes to the necessary authority or to the nearest policeman.



Be extremely careful to prevent fires starting or to prevent injuries as a result of falling objects.



Use the telephone for emergencies only.

**YOUR ABILITY TO HANDLE EMERGENCIES  
WILL HELP AND INSPIRE OTHERS**

**U.S. DEPARTMENT OF COMMERCE • WEATHER BUREAU**

### **DISASTER MANAGEMENT**

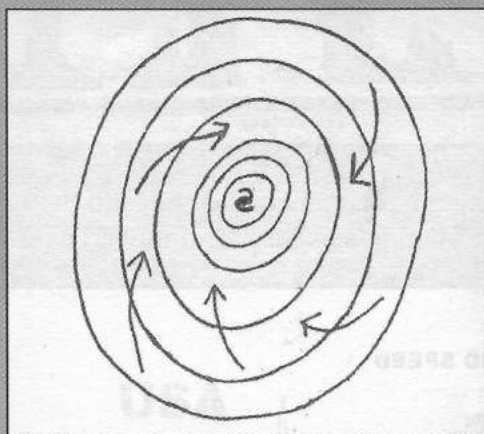
- **Evacuation of area** in order to avoid repeat of dangers of cyclone occurrence.
- Implementation of **emergency rescue operation**.
- Enlisting the assistance of the **army**.
- Providing **counselling** to those that have lost loved ones.
- Enlisting the assistance of **global organisations** such as the FAO, the WHO and the WFP.
- Provision of **temporary shelter** to those affected.
- Provision of **emergency medical and health services**.

- Ensuring that the area is **easily accessible** to all agencies involved in the management of the disaster.
- **Local authorities** to be fully involved in the **relief programme**.

### **ACTIVITY 8**

Work through the following activity on your own.

Study the diagram of a tropical cyclone and answer the questions that follow.



1. State **three** characteristics of a tropical cyclone that are evident on the diagram. [6]
2. Explain why the centre of a cyclone is associated with calm, cloudless conditions. [4]
3. Explain **two** factors that are responsible for the decay of tropical cyclones. [6]
4. Copy down the diagram and insert the wind direction assuming that the coriolis force is not in operation. [4]

**TOTAL: 20**

### **ACTIVITY 9**

Work through the following activity on your own and submit to your teacher for assessment.

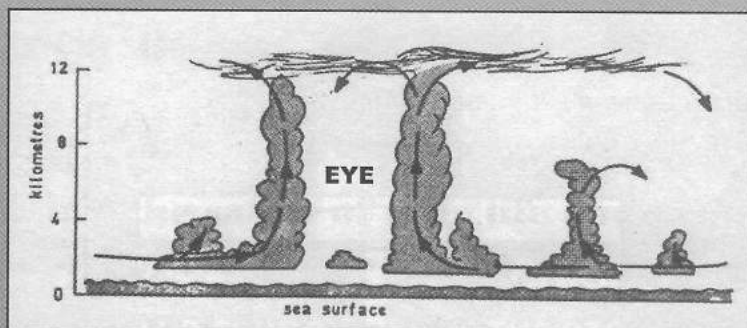
Refer to the cross section below which represents a tropical cyclone that formed over the Indian Ocean near Mauritius.

1. In which general direction will this cyclone move? [2]
2. Name the cloud type which occurs at the edge of the eye. [2]
3. Give the approximate height (depth) of the tropical cyclone. [2]
4. What will the approximate atmospheric pressure reading be at the centre [2]

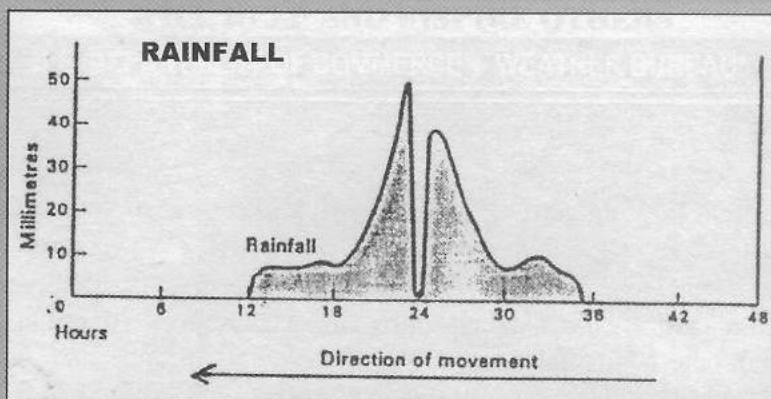
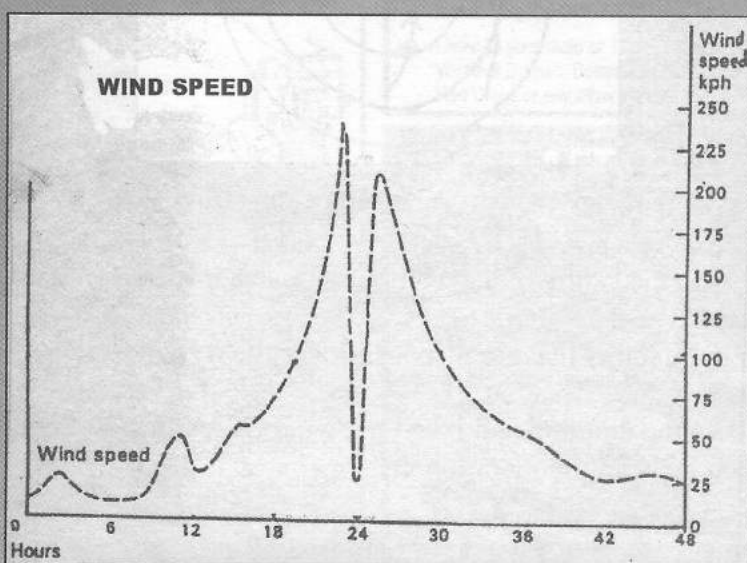
of the storm?

[2]

5. List **four** conditions required for the formation of this storm. [8]
6. State the approximate time of year (season) that this storm occurred. [2]
7. Describe **three** different air movements which occurred during the mature stage of this storm. [6]



8. With reference to the two graphs below, explain the weather conditions experienced by the islanders as the storm moved over Mauritius. [8]



9. Describe some of the environmental damage this tropical storm may cause on the island. [6]
10. Suggest precautions the islanders could take to minimize the damage

caused by this storm.

[6]

11. Suppose the island has been devastated by the tropical storm. Assume that you are a member of the WHO (World Health Organisation). Suggest **three** measures you would implement to manage the disaster.

[6]

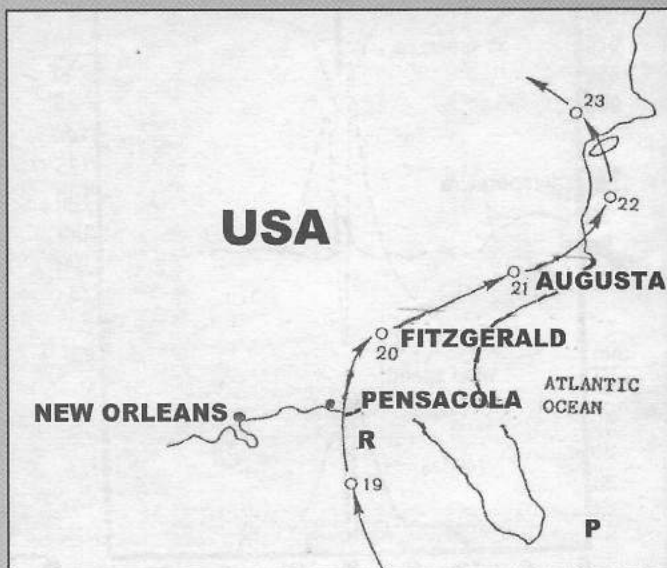
**TOTAL MARKS: 50**

### ACTIVITY 10

Work through the following activity.

Study the sketch map showing the path of hurricane Agnus.

NB. The numbers on the sketch map refer to dates.

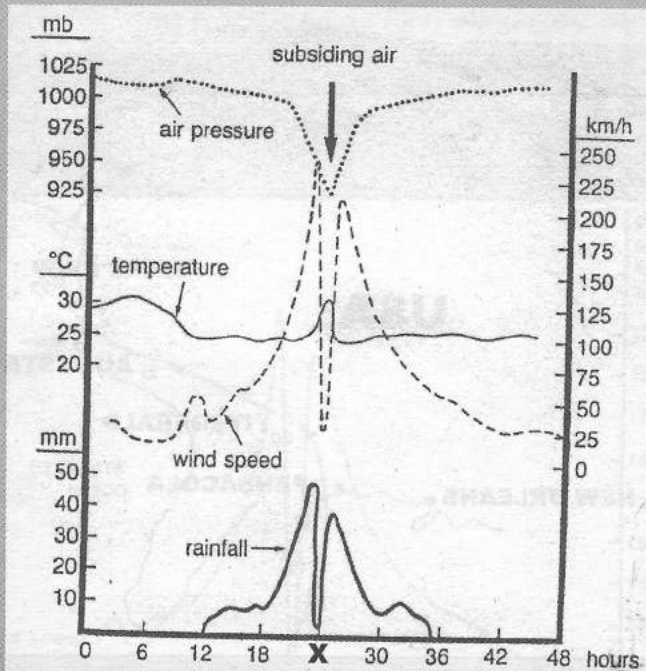


1. Name the gulf marked R.
2. What evidence suggests that the ocean marked P is warm?
3. Hurricane Agnus is most likely to have developed/originated between...
  - A.  $0^{\circ}$  and  $5^{\circ}$  N
  - B.  $5^{\circ}$  N and  $20^{\circ}$  N
  - C.  $5^{\circ}$  S and  $20^{\circ}$  S
  - D.  $0^{\circ}$  and  $5^{\circ}$  SGive a reason for your answer.
4. Assume that you live in Pensacola. List any **three** precautions you would take immediately after a hurricane warning is sounded.
5. Give **two** reasons for people in less developed countries either not heeding a hurricane warning or choosing to ignore it.
6. In which **one** of the towns/cities, Pensacola, Fitzgerald or Augusta would the hurricane probably have caused the least damage to the environment? Give a reason for your answer.

7. In spite of advanced technology it is difficult to predict the exact path/track a hurricane is likely to follow.  
Give a reason for this.

### ACTIVITY 11

Refer to the graphs below showing surface weather conditions associated with a tropical cyclone. The “eye” of the cyclone is at point X.



1. Describe the following at point X:
  - 1.1. Air pressure
  - 1.2. Air temperature
  - 1.3. Wind speed
  - 1.4. Rainfall

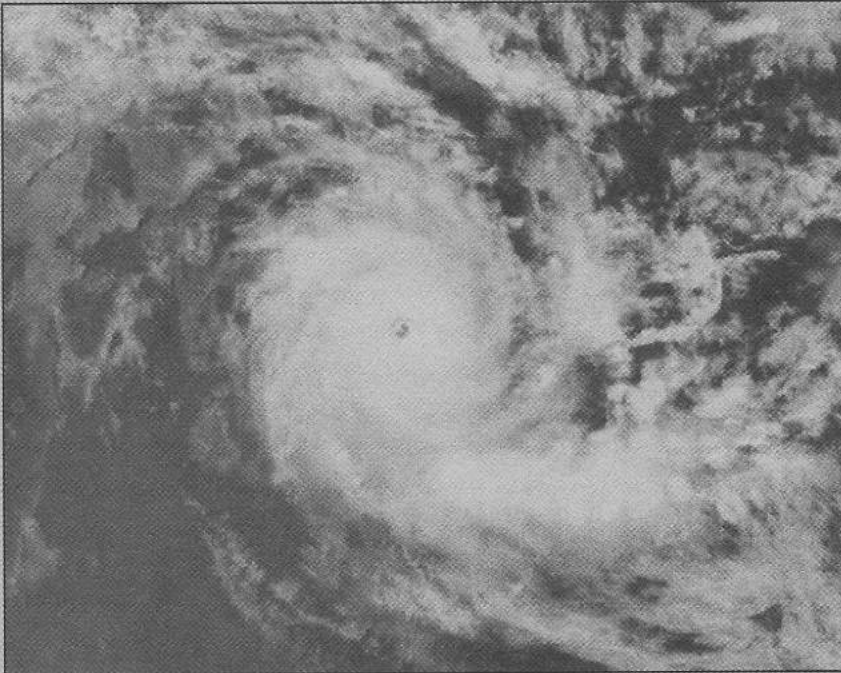
### ACTIVITY 12

Refer to the satellite image below and the extract HAITI AWAITS ANOTHER NATURAL DISASTER and answer the questions that follow.

## HAITI AWAITS ANOTHER NATURAL DISASTER

Recently Haiti, a developing country, was hit by a massive earthquake which caused a lot of damage and loss of life. After the earthquake the cholera spread rapidly through the affected areas. Haiti is now bracing itself for a hurricane that is expected to hit the country. Due to the earthquake many people are living in tents and makeshift homes. Many of the trees have been cut to produce coal which is used as an energy source. A greater amount of flooding and mudslides are expected due to the removal of the trees. The spread of cholera is expected to reach catastrophic proportions and the loss of life is expected to increase drastically.

4 November 2010



1. Identify the weather system shown in the satellite photograph.
2. State **two** weather conditions associated with this weather system.
3. Which part of this weather system is considered the most dangerous? Give a reason for your answer.
4. More 'super hurricanes' are occurring recently. Explain the reason for this.
5. In many cases, especially in developing countries, the effect of natural disasters on the economy, living conditions and loss of life is greater after a natural disaster has occurred. Explain **two** reasons for this.

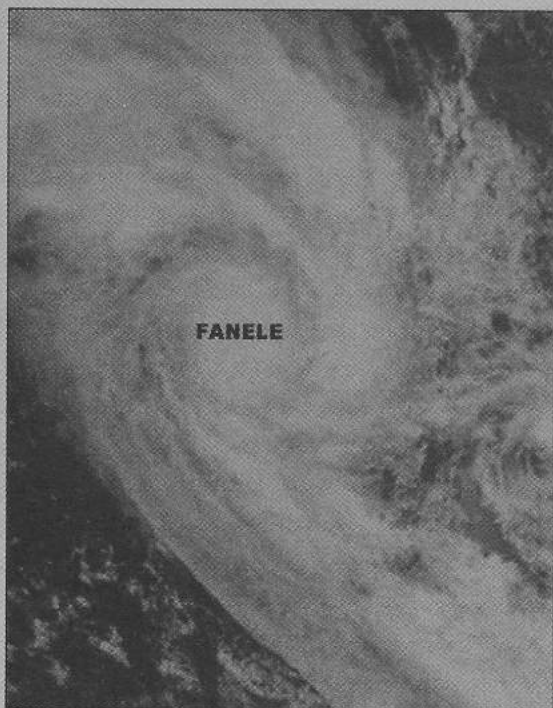
## ACTIVITY 13

Study the extract below and the satellite image of tropical cyclone Fanele and answer the questions that follow.

## ***Tropical cyclone Fanele leaves trail of destruction in Madagascar***

For several days in the middle of January 2009, a very weak low - level circulation persisted in the Mozambique Channel. Environmental conditions favoured the rapid development of the cyclone. Fanele quickly strengthened, developing an eye feature late on 19 January.

Fanele slammed into Madagascar in the early hours of Wednesday morning at wind speeds of up to 260 kilometres per hour. As it passed over the southern highlands it weakened quickly over the land. Within four hours of moving ashore its wind speed decreased and the eye feature dissipated on 23 January 2009.



1. State **one** condition that would have favoured the initial development of tropical cyclone Fanele.
2. Give **one** piece of evidence from the satellite image to suggest that tropical cyclone Fanele is in its mature stage.
3. What evidence shows that Fanele is a tropical cyclone in the southern hemisphere?
4. Why does tropical cyclone Fanele generally move from east to west?
5. Explain why tropical cyclone Fanele weakens when it moves over the southern highlands of Madagascar.
6. Give **two** reasons for the impact of tropical cyclones on human life being more severe in developing than in developed countries.
7. What was the duration of tropical cyclone Fanele?

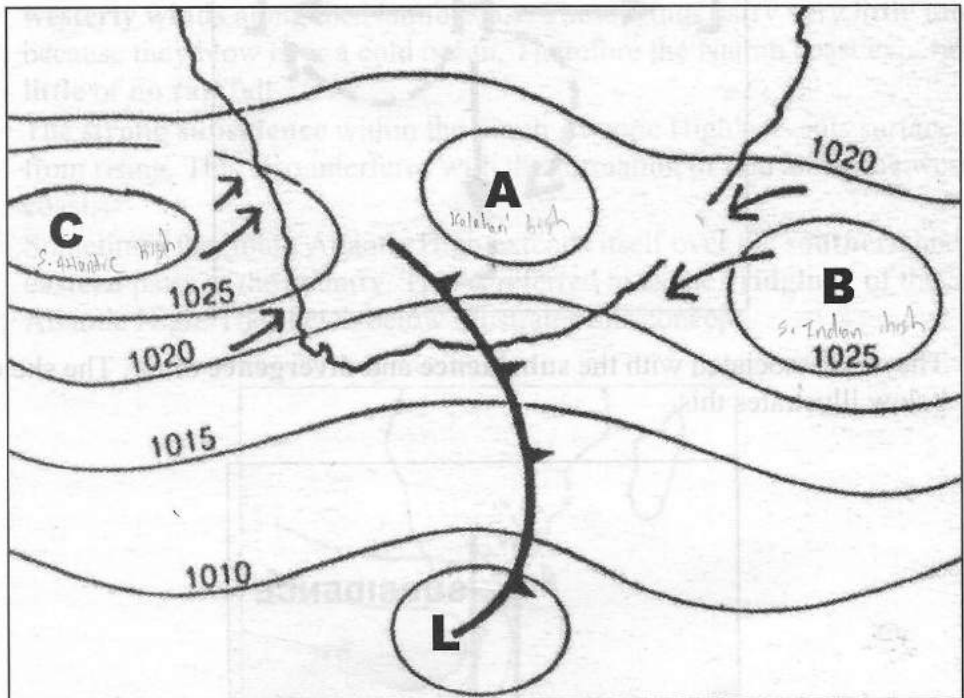
# SUBTROPICAL ANTICYCLONES AND ASSOCIATED WEATHER CONDITIONS

## INTRODUCTION

- The **pressure zone** that has a significant influence on the climate of Southern Africa is the **subtropical high pressure zone**.
- This pressure zone is located at **latitude 30° S**.
- **Divergence** and **subsidence** occur in this high pressure zone.
- The **subtropical high pressure zone** is broken up into **high pressure cells** since the surface along the 30° S latitude is **not homogeneous**. The surface is made up of **land masses** and **oceans** which react differently to temperature and pressure.

## LOCATION OF THE HIGH PRESSURE CELLS THAT AFFECT SOUTH AFRICA

The map below shows the location of the **three anticyclones** that influence the weather and climate of South Africa.



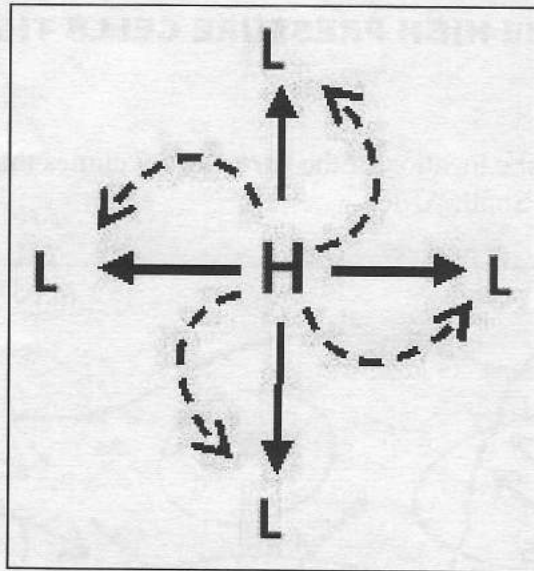
A: Continental High / Kalahari High: The Continental High is situated over the **interior** of the country.

B: South Indian High / Mauritius High: The South Indian High is located over the **South Indian Ocean** somewhere to the **east of Durban**.

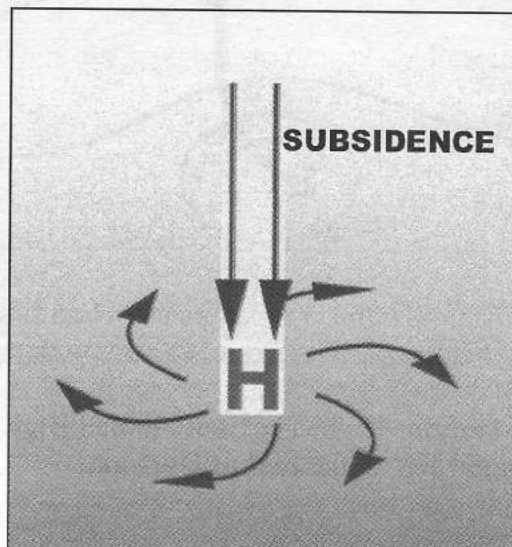
C: South Atlantic High / St Helena High. The South Atlantic High is located over the South Atlantic Ocean to the west of the Namib coast.

## GENERAL CHARACTERISTICS OF THESE HIGH PRESSURE CELLS

- Originate in the **sub - tropical high pressure zone**.
- Located at approximately **30° S latitude**.
- The high pressure cells **migrate** with the **apparent migration** of the sun.
- They lie **further north** in winter and **further south** in summer.
- They are **semi - permanent** weather systems.
- They are **semi - stationary** weather systems.
- In winter they lie **closer** to the coast whilst in summer they move **further away** from the coast.
- Air circulates in an **anticlockwise** direction around the high pressure system. The sketch below illustrates this.



- They are associated with the **subsidence** and **divergence** of air. The sketch below illustrates this.



- They are **better developed** in winter.
- The South Indian High and the South Atlantic High are present **throughout the year**, whilst the Continental High is only present in **winter**.

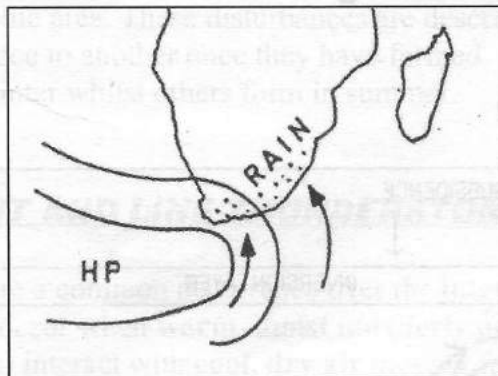
## **ANTICYCLONIC AIR CIRCULATION AROUND SOUTH AFRICA AND ITS INFLUENCE ON WEATHER AND CLIMATE**

### **THE EFFECTS OF THE SOUTH INDIAN HIGH**

- The anticyclonic circulation of air in the South Indian High causes **north easterly onshore winds** along the coast of KwaZulu - Natal. These winds are **warm, moist and unstable**. These winds are significant because the advection of warm, moist air over the coastal area of KwaZulu - Natal results in **high rainfall** particularly in summer.
- Sometimes the South Indian High prevents the westward movement of mid - latitude cyclones. It is then referred to as a **“blocking high”**. The blocking high causes mid - latitude cyclones to move in a south easterly direction.
- It also **prevents tropical cyclones** from moving in a southerly direction.

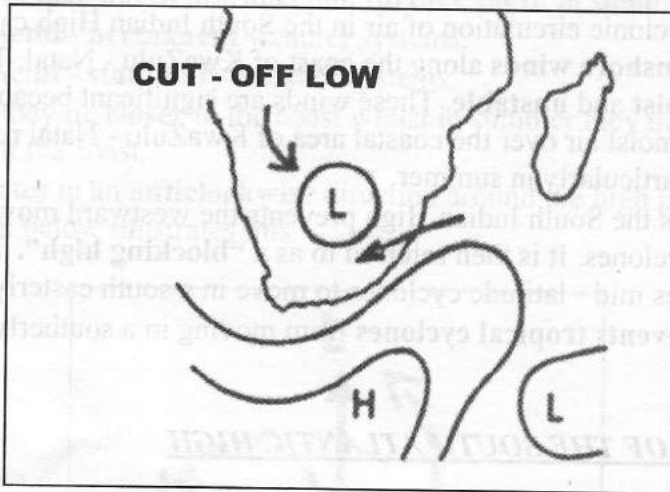
### **THE EFFECTS OF THE SOUTH ATLANTIC HIGH**

- The anticyclonic circulation of air in the South Atlantic High causes **south westerly winds** along the Namib coast. These winds carry very **little moisture** because they blow over a cold ocean. Therefore the Namib coast experiences **little or no rainfall**.
- The **strong subsidence** within the South Atlantic High prevents surface air from rising. This also interferes with the formation of rain along the west coast.
- Sometimes the South Atlantic High extends itself over the **southern and south eastern** parts of the country. This is referred to as the **“ridging”** of the South Atlantic High. The sketch below illustrates this concept.



- The ridging is significant because it enables cool, moist air to be advected onto land and this leads to **rainfall** over the southern and eastern parts of the country.

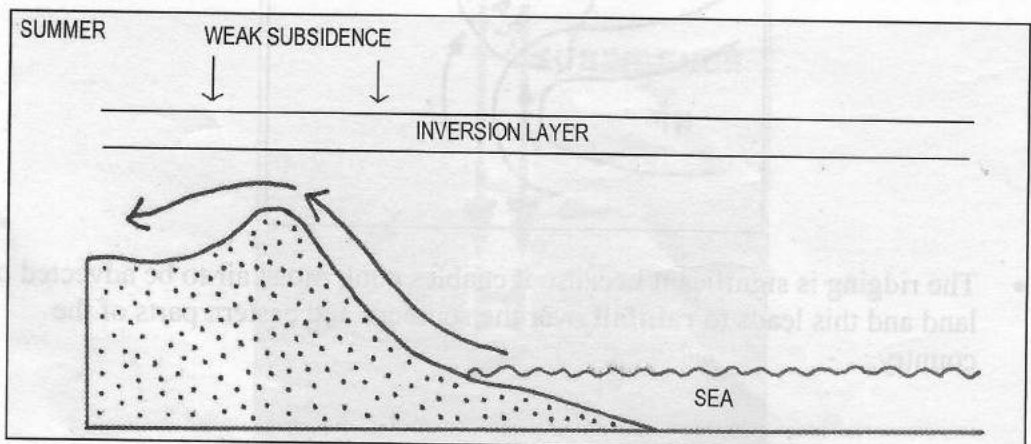
- The South Atlantic High sometimes leads to the formation of a **cut - off low**. A cut - off low is an **inland depression** (low pressure system) that is prevented from moving towards the east because of an **anticyclone** that lies in its path. It is formed when the South Atlantic High (refer to map) **ridges** between the **inland depression** and a **depression** found to the **east** of the country. The formation of the cut - off low is significant because it draws onto the land moist air from the ocean which causes **rainfall** for several days. The devastating floods that occurred in KwaZulu - Natal in September 1987 were caused by a cut - off low. The map below illustrates a cut - off low.



### THE EFFECTS OF THE CONTINENTAL HIGH

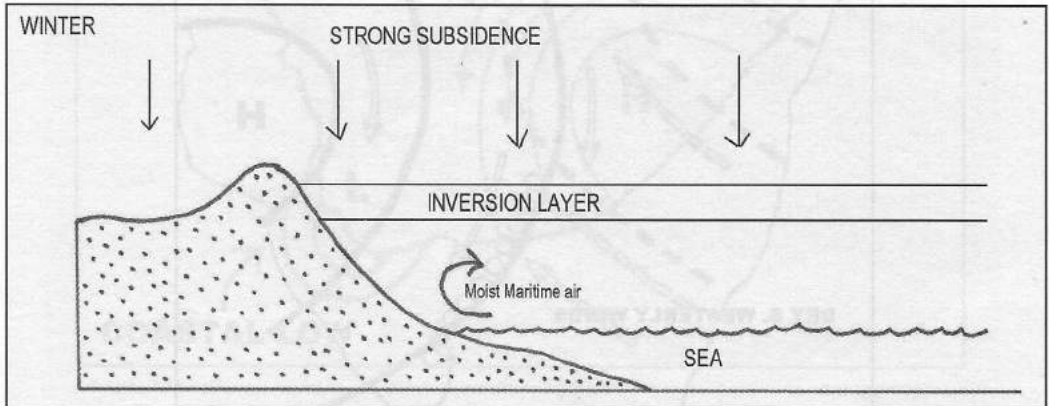
- The Continental High and its associated subsidence are responsible for the generally **fine weather** over the interior of South Africa.
- Subsidence** within the Continental High results in the formation of an **inversion layer** which affects the rainfall pattern of Southern Africa. **The sketches below illustrate the position and effects of the inversion layer during summer and winter.**

### Summer Situation



During **summer** there is **weak subsidence** in the Continental High. This results in the formation of an **inversion layer** which is also **weakly developed**. The inversion layer lies at a height of about **1 kilometre** above the **plateau**. This allows warm moist air from the Indian Ocean to be advected onto the plateau. Thus the plateau experiences **high rainfall** during summer. This impacts **positively** on **crop** and **stock farming** on the plateau.

### **Winter Situation**



During **winter** there is **strong subsidence** in the Continental High. This causes the inversion layer to lie **below** the level of the plateau. As a result warm moist air from the Indian Ocean is **not able** to get onto the plateau. Therefore the plateau experiences **dry conditions** during winter. The dry conditions impact **negatively** on agricultural activities on the plateau.

**NB.** During summer the Continental High may be replaced by a **Continental Low** (thermal / heat low).

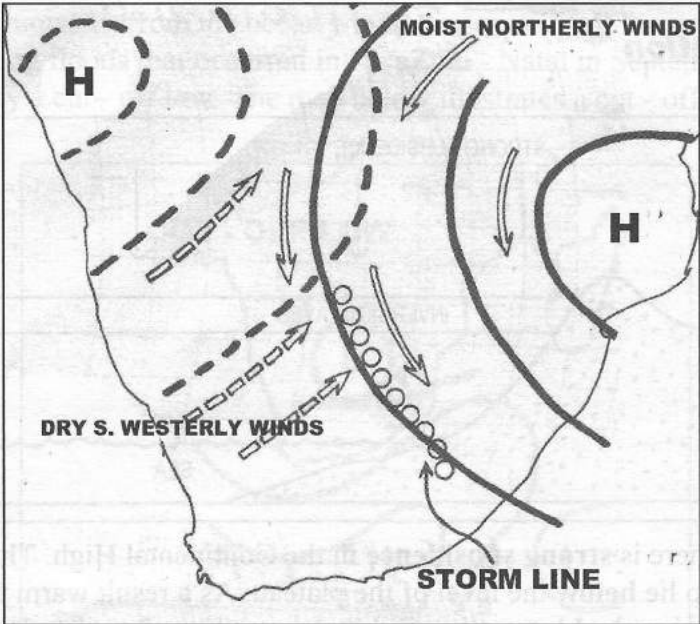
### **TRAVELLING DISTURBANCES ASSOCIATED WITH ANTICYCLONIC CIRCULATION**

There are several disturbances in the atmosphere that are not permanently located over a specific geographic area. These disturbances are described as **travelling** since they move from one place to another once they have formed. Some of these disturbances form in winter whilst others form in summer.

### **MOISTURE FRONT AND LINE THUNDERSTORMS**

**Line thunderstorms** are a common occurrence over the **interior** of South Africa during **summer**. They occur when **warm, moist northerly** or **north easterly winds** (from the Indian Ocean) interact with **cool, dry air** moving from the **south west** (from the Atlantic Ocean). The zone where these two air masses meet is referred to as the **moisture front**. At the moisture front, the warm moist air is forced to **rise** over the cool dry air. This leads to condensation, cloud formation and thunderstorm activity along the moisture front. These storms are associated with **thunder**,

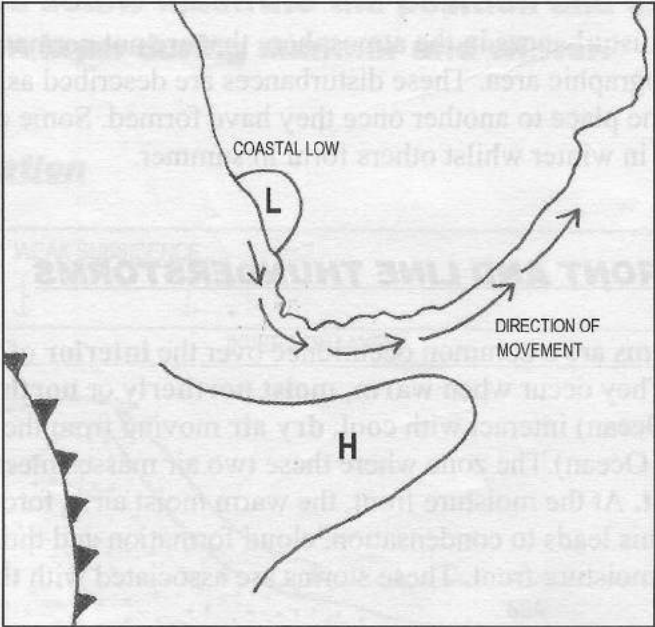
**lightning, hail and heavy rainfall** which may result in **flash floods**. Heavy rainfall occurs to the **east** of the moisture front. **Dry conditions** occur to the **west** of the moisture front. The moisture front is also known as the **squall line** or **storm line**. The map below shows the occurrence of the moisture front and line thunderstorms



**COASTAL LOW PRESSURE SYSTEM**

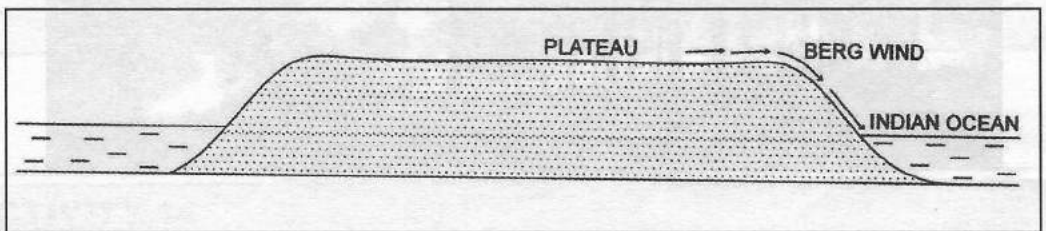
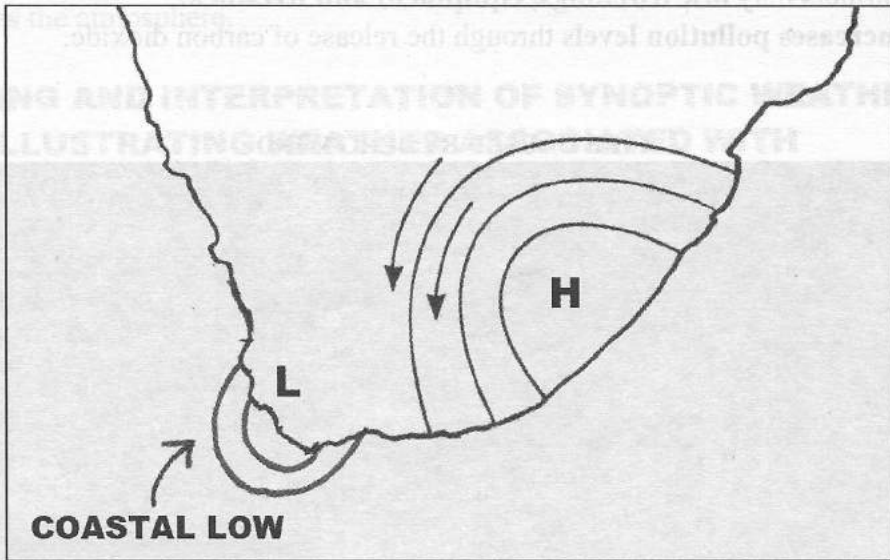
The coastal low is a **mini - low pressure cell** that originates along the **west coast** of South Africa. It moves in an **erratic manner** along the coast in a **south easterly direction** and then in a **north easterly direction**. It has a diameter of about 100 kilometres. It is associated with **partly cloudy** conditions and sometimes **light drizzle**. A coastal low is also responsible for the formation of **berg winds**.

**COASTAL LOW AND DIRECTION OF MOVEMENT**



## **SOUTH AFRICAN BERG WIND**

The **map** and the **sketch** below illustrate the development of a berg wind.



The **interaction** between the **coastal low** and the **continental high** results in the formation of a berg wind. The **high pressure** system forms over the north eastern part of the country during winter because of the low temperature. A coastal low develops along the coast. The **continental high** circulates air in an **anticlockwise direction** into the **coastal low**. The air has to **descend** the plateau in order to reach the coastal low. As the air descends, it is **warmed adiabatically**. The descending air thus reaches the coast as a **hot wind** known as the berg wind. Berg winds occur along the eastern, southern and western coastal areas. Berg wind conditions spread along the coast with the movement of the coastal low. The berg wind is a **dry wind** since it is an **offshore wind**. These winds may blow for two or three days at a stretch. Berg winds occur in **winter** and are most frequent along the **west coast**.

The following weather systems are evident on a synoptic weather map during berg wind conditions: the **Continental High**, a **coastal low**, and an **approaching mid-latitude cyclone**.

### **What are the effects of berg winds?**

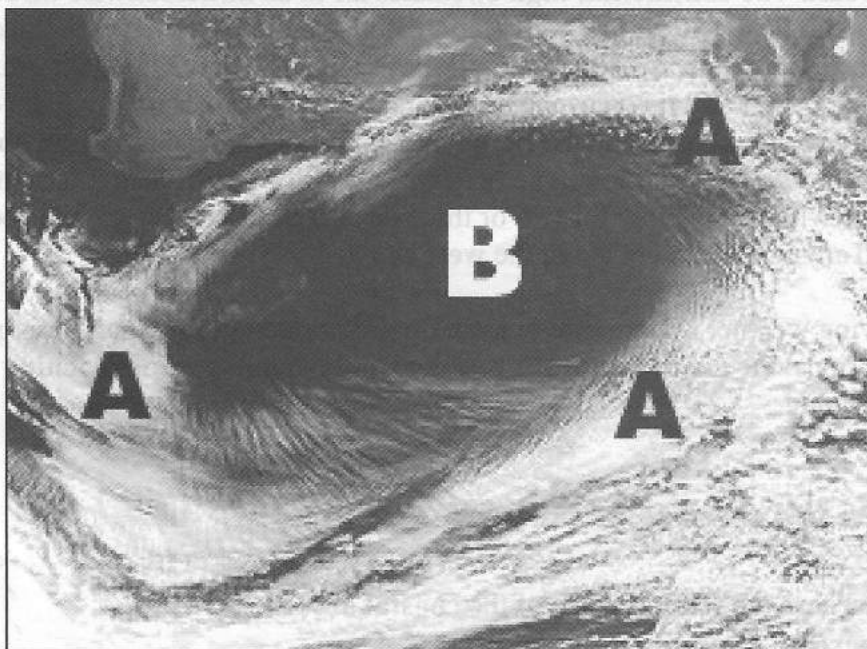
- Increase the temperature of the coastal areas.
- Decrease atmospheric humidity.

- There is an **increase** in the incidence of **veld fires and forest fires**.
- **Lowers** work output. People become **lethargic**.
- **Wild life habitats** are destroyed.
- Farmers may **lose dwellings, equipment and livestock**.
- **Increases pollution levels** through the release of carbon dioxide.

**FIRE CAUSED BY BERG WIND**

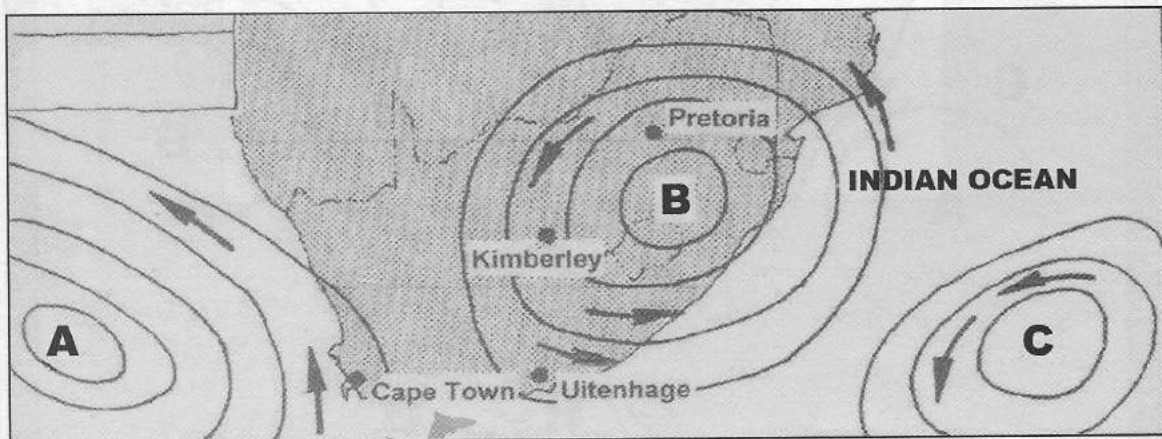


## **READING AND INTERPRETATION OF SATELLITE IMAGE ILLUSTRATING WEATHER ASSOCIATED WITH SUBTROPICAL ANTICYCLONIC CONDITIONS**



The satellite image above shows a well developed anticyclone in the **southern hemisphere**. The **anticlockwise circulation** of air is evident in the vicinity of A. Note the **clear weather conditions** in the vicinity of B. The clear weather conditions are the result of the **strong subsidence** of air within the anticyclone. The subsidence **stabilizes** the atmosphere.

## READING AND INTERPRETATION OF SYNOPTIC WEATHER MAP ILLUSTRATING WEATHER ASSOCIATED WITH SUBTROPICAL ANTICYCLONIC CONDITIONS



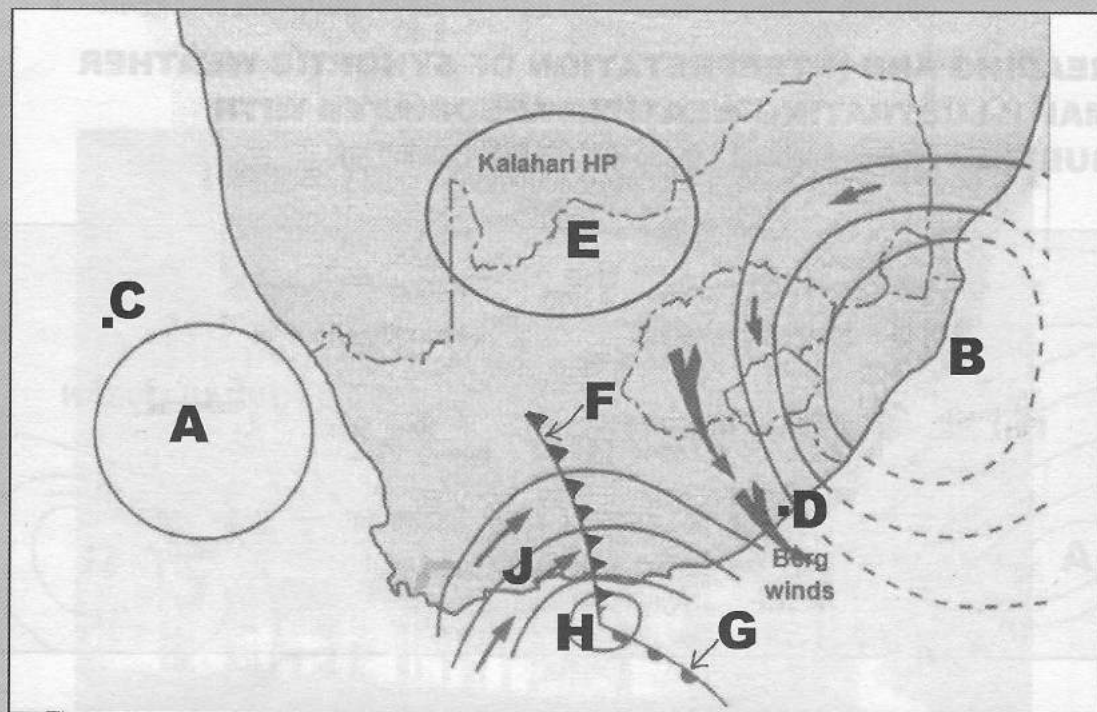
### ACTIVITY 14

Refer to the synoptic weather map above showing the position of the three high pressure cells over southern Africa.

1. Identify the high pressure cells labelled A, B and C.
2. Describe the air circulation associated with these high pressure cells.
3. The synoptic map represents a winter situation.  
Give **three** reasons to support this statement.
4. Explain why high temperatures are being experienced in the vicinity of Uitenhage.
5. Which one of the high pressure cells (A, B or C) is mainly responsible for the different weather conditions experienced over the South African interior during summer and winter?
6. Explain how the high pressure cell referred to in question 5 affects the rainfall pattern over the interior of South Africa.

## ACTIVITY 15

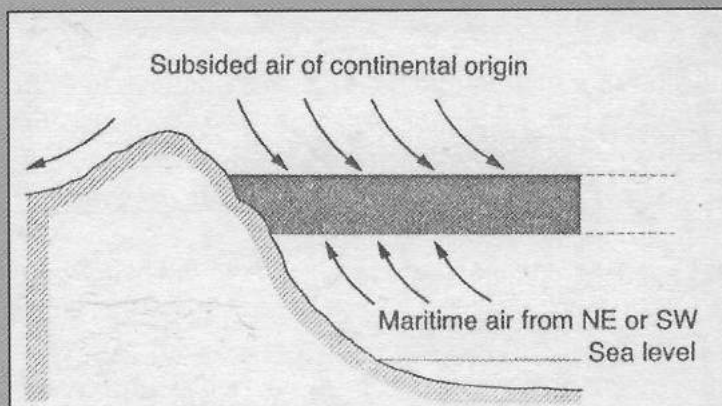
Study the sketch below and answer the questions set.



1. Name the high pressure cells labelled A and B.
2. The sketch represents a winter situation.  
Give **four** reasons to support this statement.
3. Describe the air circulation in the high pressure cell labelled A.
4. Rain is unlikely to occur in the vicinity of C.  
Explain the reason for this.
5. Explain why high temperatures are being experienced in the vicinity of D.
6. Describe the likely weather conditions prevailing in the vicinity of E.
7. Name the front labelled F.
8. Name the front labelled G.
9. Explain why the front labelled G seldom affects the weather of South Africa.
10. Name the weather system labelled H.
11. In which direction is the weather system labelled H likely to move?
12. Give a reason for your answer to question 11.
13. Overcast conditions with rain are likely to be occurring in the vicinity of J.  
Give a reason for this.
14. Explain why warm moist air from the Indian Ocean cannot be advected into the interior of the country during the season represented in the sketch.
15. Explain why tropical cyclones seldom affect the weather of South Africa.
16. Name the environmental hazard (danger) that is associated with the development of berg wind conditions.
17. Which weather system is responsible for the termination (ending) of berg wind conditions?

## ACTIVITY 16

Study the sketch and answer the questions that follow.

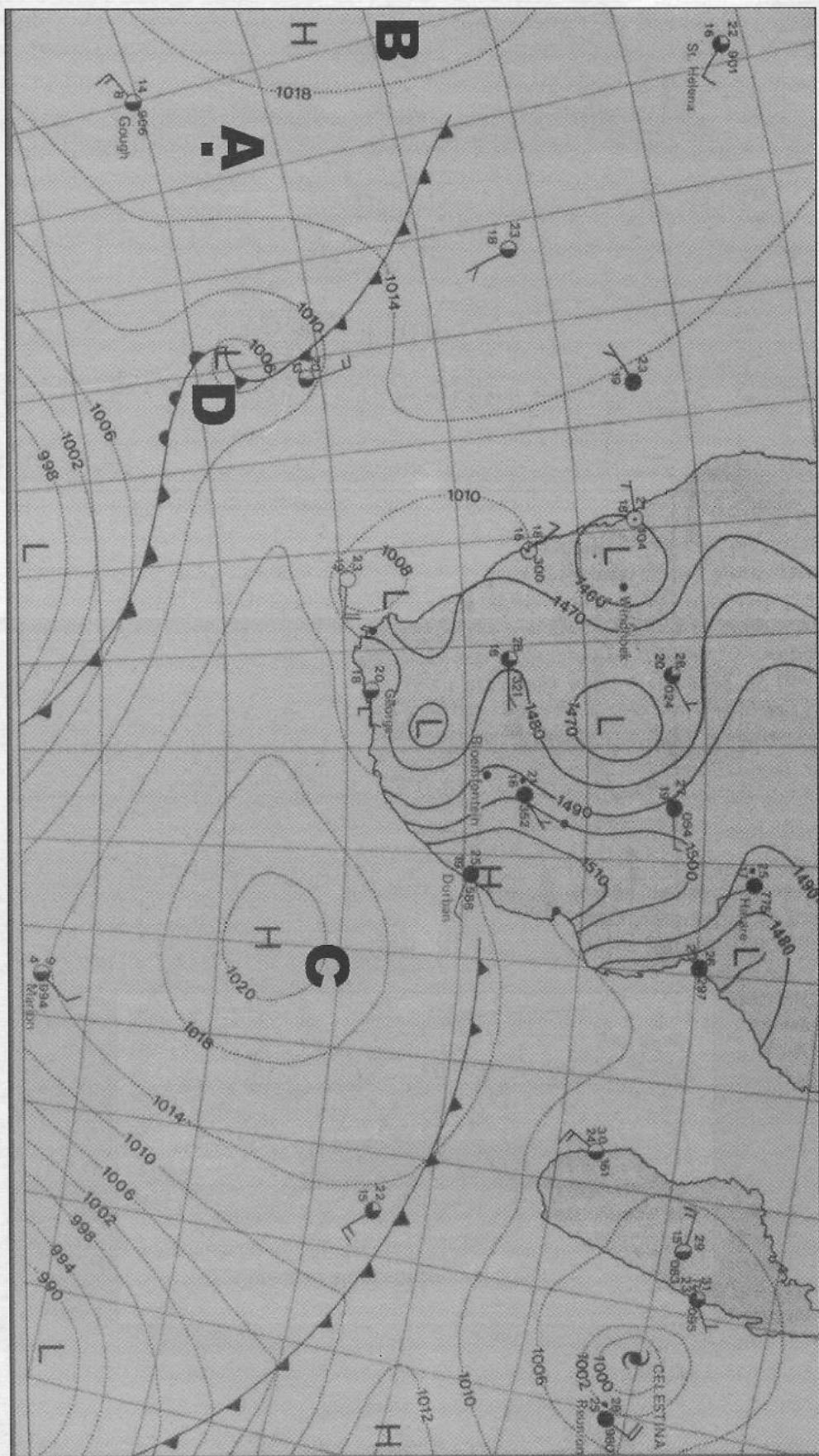


1. Explain the term temperature inversion.
2. State the season represented.  
Give a reason for your answer.
3. What is the relationship between temperature and height in the inversion layer?  
Give a reason for this.
4. Explain the development and location of the inversion zone.
5. Evaluate the significance of the weather conditions to the farmers on the Highveld if the atmospheric conditions represented prevail throughout the year.

## ACTIVITY 17

Study the synoptic weather map on the next page and answer the following questions.

1. Why is the map called a synoptic map?
2. Does the map illustrate summer or winter conditions?
3. Give a reason for your answer to question 2.
4. What is the isobaric interval of the map?
5. State the atmospheric pressure at the point labelled A.
6. Identify the high pressure cells labelled B and C.
7. Describe the weather being experienced at Durban.
8. Give a reason for the weather conditions being experienced at Durban.
9. Identify the weather system located to the east of Madagascar.
10. Identify the weather system labelled D.
11. In what stage of development is the weather system labelled D?




















# **SYNOPTIC WEATHER MAP READING AND INTERPRETATION (REVISION OF WORK COVERED IN GRADE 10 AND 11)**

The basic principles of synoptic weather map interpretation have been dealt with in grade 10. Refer to “Geography Grade 10: A Handbook for Learners” and “Geography Grade 11: A Handbook for Learners”. **This section has been repeated in this handbook for the purpose of revision.**

The information provided below must be studied together with the **synoptic weather map dated 941206**.

- The word **synoptic** is derived from synopsis which means **summary**. A synoptic weather map is, therefore, a **summary of prevailing weather conditions** over a certain area at a specific time.
- Aspects such as **temperature, nature of precipitation, cloud cover, wind direction and wind speed** are indicated at **weather stations** by means of **symbols**.

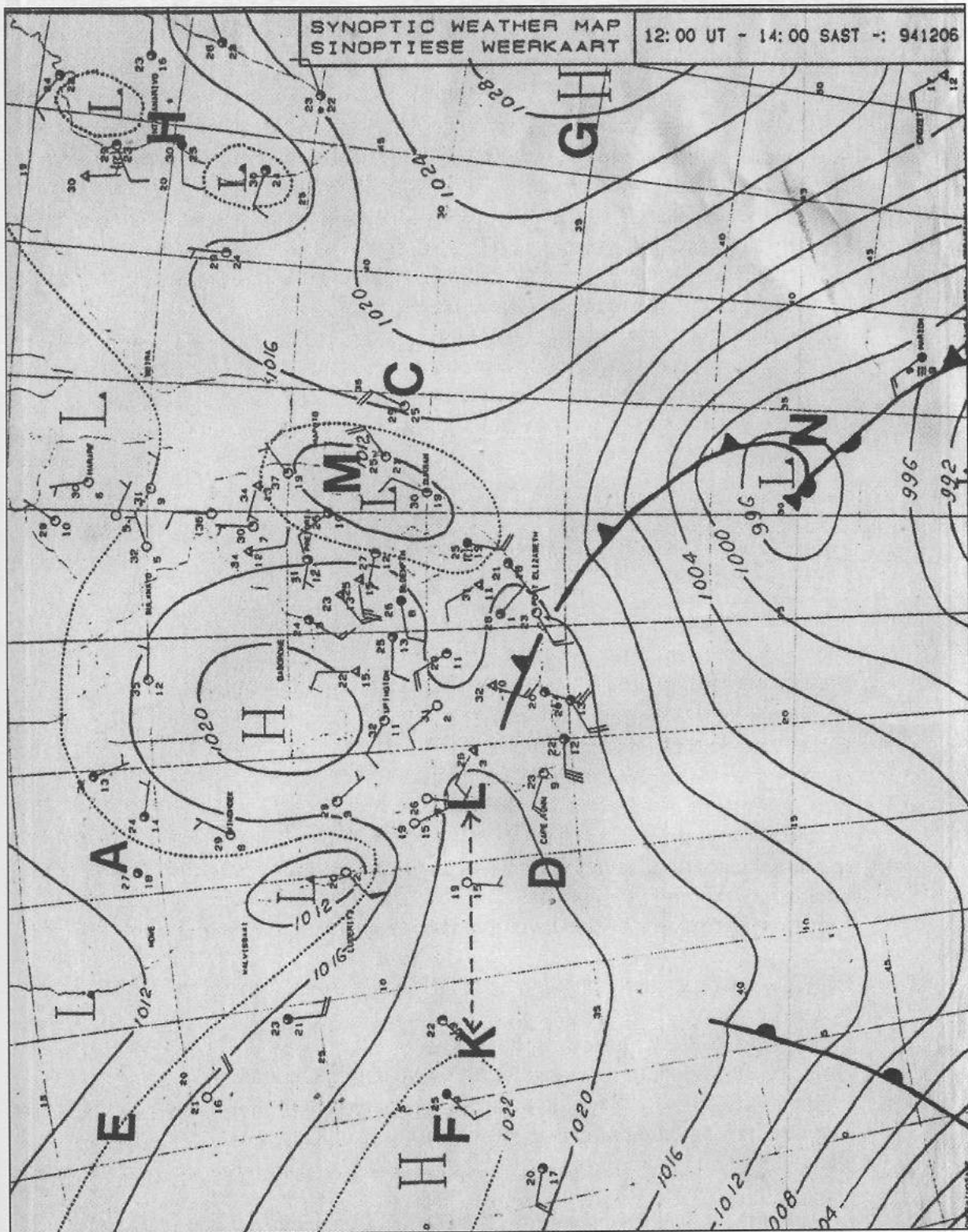
CLOUD COVER		WEATHER SYMBOLS USED	
 NO CLOUD	 5/8 CLOUD	 RAIN	 SNOW
 1/8 CLOUD	 6/8 CLOUD	 DRIZZLE	 HAIL
 2/8 CLOUD	 7/8 CLOUD	 SHOWERS	 MIST
 3/8 CLOUD	 OVERCAST	 THUNDERSTORM	
 4/8 CLOUD	 SKY NOT VISIBLE BECAUSE OF DUST, SMOKE, ETC.		

- **Dew point temperature and air temperature:** The difference between the dew point temperature and the air temperature gives an indication of the **moisture content** of the air. With reference to the weather station labelled A, the air temperature is 27°C and the dew point temperature is 18°C.
- **Wind direction:** Note that a wind is named according to the direction from which it is blowing.
- **Wind speed:** Wind speed is represented by means of a “feather”. A long feather represents **10 knots** and short feather **5 knots**. The wind speed at the weather station labelled C is 20 knots and the wind direction is north easterly.
- **Isobars:** The continuous lines over the ocean and land are **isobars** whilst the dotted lines are **sub - isobars**. On the weather map, the line labelled D is an isobar whilst the line labelled E is a sub - isobar.

*Various weather (air pressure) systems and patterns appear on a weather map. Some of these are listed below.*

- **Anticyclones:** An anticyclone is indicated by the letter **H** on a weather map. The isobars are more or less **circular** in shape. The highest pressure reading is at the centre. F on the map is the South Atlantic Anticyclone whilst G is the South Indian Anticyclone.
- **Cyclones:** A cyclone is indicated by the letter **L** on a weather map. The isobars are more or less **circular** in shape. The lowest pressure reading is found at the centre.
- **Saddle:** The area found between **two high or low pressure** systems, for example, H on the map.
- **Trough:** The elongated part of a **low pressure system**
- **Ridge:** The elongated part of a **high pressure system** (K - L on weather map).
- **Coastal Low:** A weakly developed low pressure along the **coast** (M on map).
- **Mid - latitude cyclone:** These cyclones are identified by the presence of **fronts** (N on map).
- **Tropical cyclones:** These cyclones are characterized by an absence of fronts and the presence of the **eye**. They have names, for example, Barbara.
- **Summer map:** The following are typical characteristics of a summer situation on a weather map:
  - **High temperatures** over land.
  - Mid - latitude cyclones occupy a **southerly** position.
  - Presence of **tropical cyclones**.
  - **Date** indicated on a map, for example, 071030.
  - High pressure systems occupy a **southerly** position.
  - Presence of **low pressure systems** over land.
  - High pressure systems lie further away from the coast.
- **Winter map:** The following are typical characteristics of a winter situation on a weather map:
  - **Low temperatures** over land.
  - Presence of **cold front** over land.
  - The country is dominated by **high pressure systems**.
  - High pressure systems occupy a **northerly** position.
  - **Date** indicated on map, for example, 070628.
  - High pressure systems lie closer to the coast.
- The synoptic weather map dated 941206 is a summer map.

12:00 UT - 14:00 SAST -: 941206

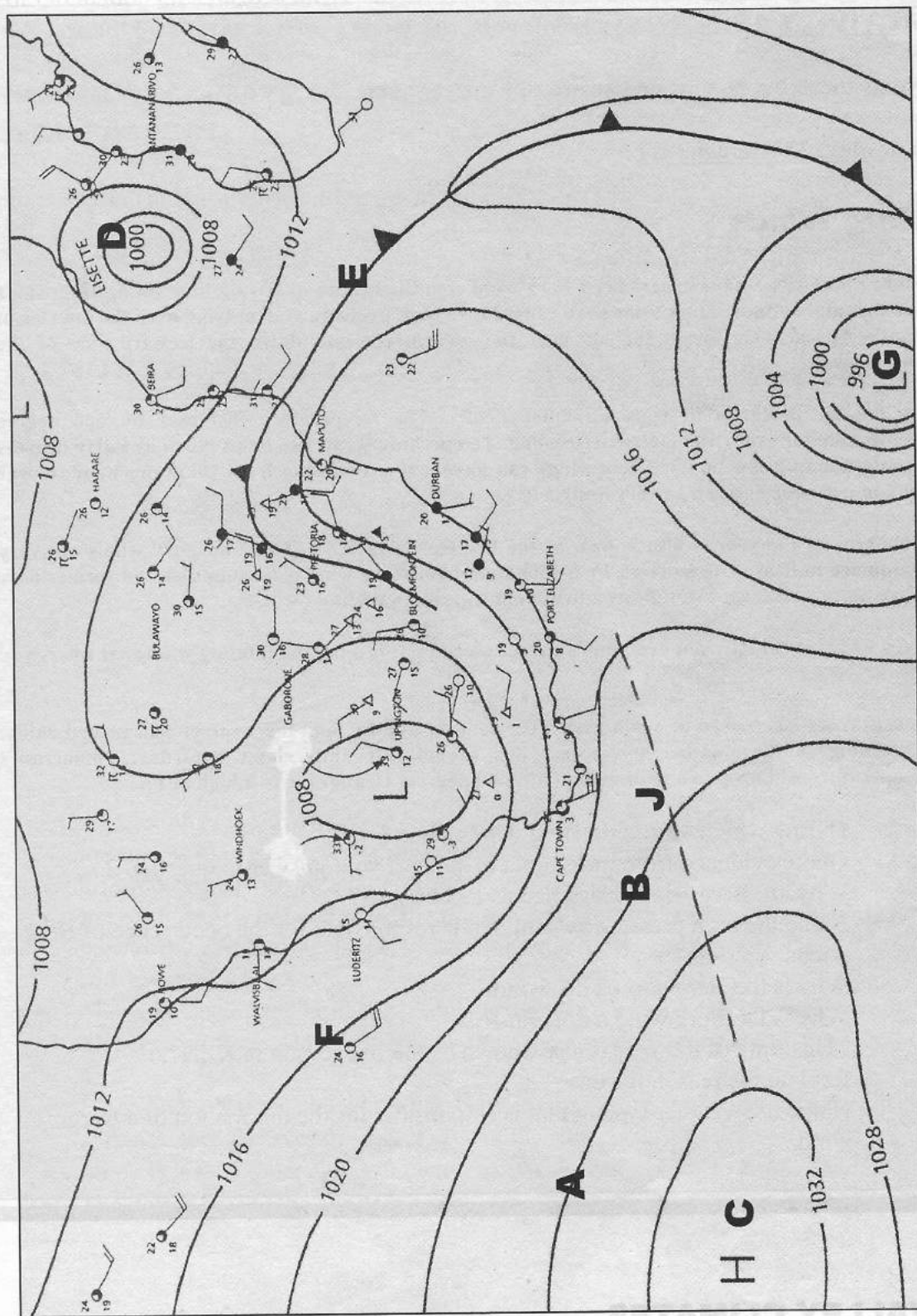


**ACTIVITY 18: ASSESSMENT ACTIVITY****TOTAL MARKS: 100**

Work through the following activity on your own and submit to your teacher for assessment.

Study the synoptic weather map on the following page and answer the questions set.

1. Why is the map called a synoptic map? [2]
2. Identify the line labelled A. [2]
3. What is the atmospheric pressure at the point labelled B? [2]
4. With reference to the weather system labelled C:
  - 4.1. Name the weather system. [2]
  - 4.2. Is the weather system occupying a northerly or a southerly position? [2]
  - 4.3. Explain the reason for this (answer 4.2). [4]
  - 4.4. Describe the pressure gradient within this weather system.  
Give a reason for your answer. [4]
5. Does the map represent summer or winter?  
Give **three** reasons for your answer. [8]
6. Cape Town is experiencing south easterly winds.  
Explain the reason for the wind direction. [4]
7. Account for the cloudy and overcast conditions along the eastern coastal areas. [4]
8. Describe the weather being experienced at Maputo. [10]
9. Explain why South Africa is dominated by a low pressure system. [2]
10. With reference to weather system labelled D:
  - 10.1. Identify the weather system. [2]
  - 10.2. Give **two** reasons for your answer to 10.1. [4]
  - 10.3. In what stage of development is this weather system?  
Give a reason for your answer. [4]
  - 10.4. Explain what will happen to this weather system as it moves further inland. [4]
  - 10.5. Explain **two** reasons for the development of this weather system in this area. [6]
  - 10.6. Explain **two** ways in which people are adversely affected by this weather system. [6]
11. Identify the weather phenomenon labelled E. [2]
12. Describe the weather associated with this weather phenomenon. [10]
13. Explain why rain is unlikely to occur at the weather station labelled F. [4]
14. The weather system labelled G is more strongly developed than the weather system labelled D.  
Give **two** reasons to support this statement. [4]
15. Identify the atmospheric condition represented by the dashed line labelled J. [2]
16. Evaluate the importance of cyclone warning systems to people living in low lying coastal areas. [6]



## **ACTIVITY 19**

Study the extract below and answer the questions set.

Tuesday, 23 August 2011

### ***Berg Winds***

Since Sunday, we have experienced Berg wind conditions here in KwaZulu - Natal. Berg winds are mountain winds. These winds are caused by a high pressure system lying over the interior of South Africa. This forces the air over the escarpment and down the leeward side of the Drakensberg.

As the air descends it heats up adiabatically. The temperature increases by one degree Centigrade for every 100 metres descended. Temperatures can rise by as much as thirty degrees Centigrade in a few hours. These winds can have a speed varying from 10km per hour to over 100km per hour and can be very destructive.

This time of the year is also known as the fire season in KZN. These hot, 'dry winds are very conducive to fires. A fire driven by a 100km an hour Berg wind is unstoppable. No farmer dare leave his farm during this time as a fire could wipe out a lifetimes work.

Berg winds eventually put everyone's nerves on edge. It is a hot debilitating wind that wears you down.

A cold front has moved in again across the country and by 6pm the weather had turned chilly. According to the weather forecasters this should last until about Saturday. Tomorrow's temperature will drop to a minimum of about 4 degrees Centigrade to a high of 17.

1. During which season do Berg winds occur?
2. Quote evidence from the extract to support your answer to question 2.
3. Why are Berg winds classified as local winds?
4. Name the high pressure system that is responsible for the occurrence of Berg winds.
5. Why is the Berg wind a dry wind?
6. Why is the Berg wind a hot wind?
7. "This time of the year is also known as the fire season in KZN". Explain the reason for this.
8. Name the weather system that is responsible for the dissipation of a Berg wind.

## **VALLEY CLIMATES**

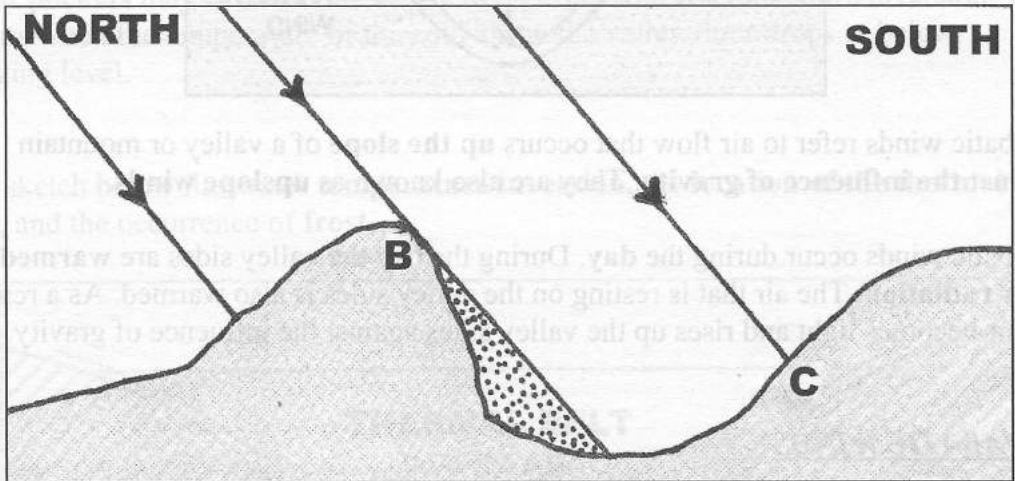
Valleys have a **distinct climate** compared to the surrounding areas. **Valley climate** is an example of **local climate**. The study of climate on a local scale is termed **microclimatology**. **Local climate** refers to the climate of a **small area**, for example, **valley climate** and **urban climate**.

Air circulation on a **local scale** is classified as **tertiary** because the air flow occurs over a **small local area** and for a **short duration** (measured in hours).

## THE MICROCLIMATE OF VALLEYS (THE EFFECT OF THE SLOPE ASPECT)

Slope aspect causes significant **temperature differences** between opposite slopes in a valley.

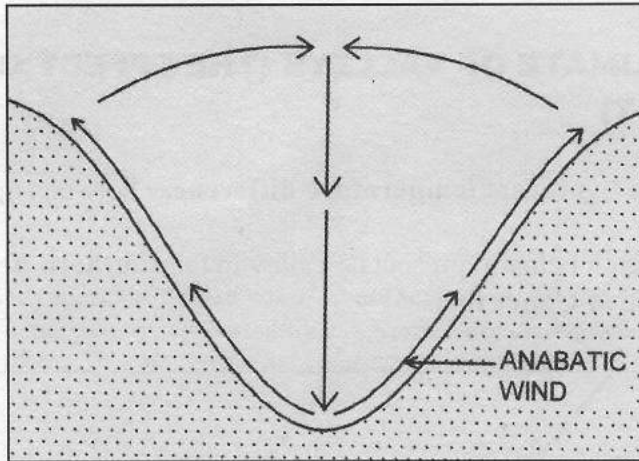
Assume that the sketch below represents a valley in the **southern hemisphere**, lying **south of the Tropic of Capricorn**.



- Aspect refers to the **direction** in which a slope faces in relation to the rays of the sun. Within a valley, the rays of the sun strike the opposite sides at different angles (**direct** and **oblique**).
- In the **southern hemisphere**, the **northward facing** slopes are **warmer** than the **southward facing** slopes whilst in the **northern hemisphere** the **southward facing** slopes are **warmer**.
- The slope facing the **equator** is always the warmer slope since it receives the **direct rays** of the sun. Furthermore the heat is spread over a small surface area.
- In the above valley, slope C is the warmer slope since it is northward facing and therefore receives the direct rays of the sun.
- Slope B is the cooler slope since it receives the oblique rays of the sun.
- The dotted area is the **shadow zone**.

## DEVELOPMENT OF ANABATIC AND KATABATIC WINDS, INVERSIONS, FROST POCKETS, RADIATION FOG

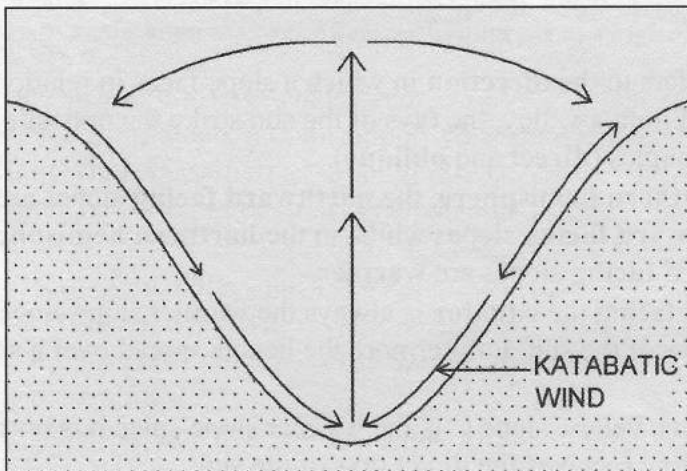
## ANABATIC WINDS



Anabatic winds refer to air flow that occurs **up the slope** of a valley or mountain **against the influence of gravity**. They are also known as **upslope winds**.

Anabatic winds occur during the **day**. During the day the valley sides are **warmed by solar radiation**. The air that is resting on the valley sides is also warmed. As a result the air becomes light and rises up the valley sides against the influence of gravity.

## KATABATIC WINDS



Katabatic winds refer to air flow that occurs **down the slope** of a valley or mountain under the **influence of gravity**. Katabatic winds are also known as **downslope winds**, **gravity winds** and **drainage winds**.

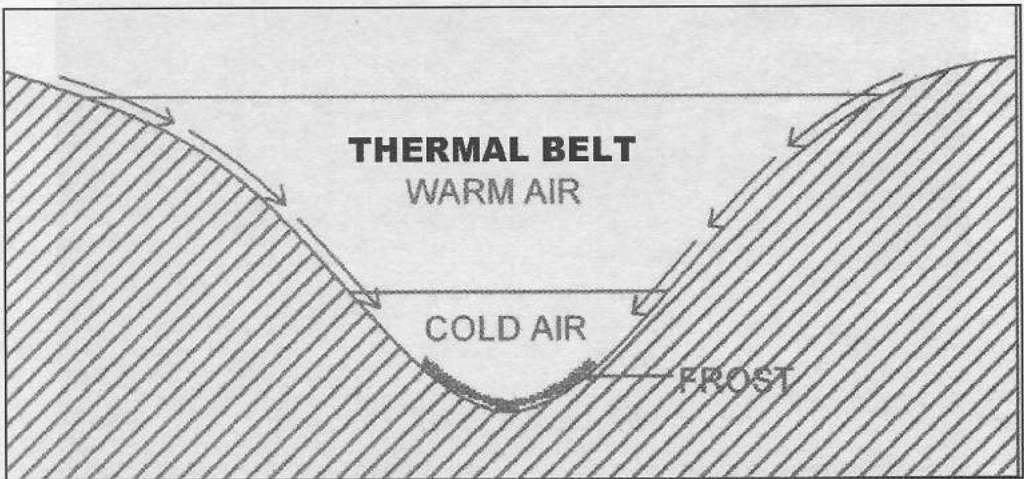
Katabatic air flow occurs during **calm winter nights**. During the **night** the valley sides are **cooled** by the process of **earth radiation**. The air that is resting on the cold valley sides also becomes cold. As a result the air becomes heavy and drains down the valley sides under the **influence of gravity**. This wind is known as a **katabatic wind**.

## TEMPERATURE INVERSIONS AND FROST POCKETS

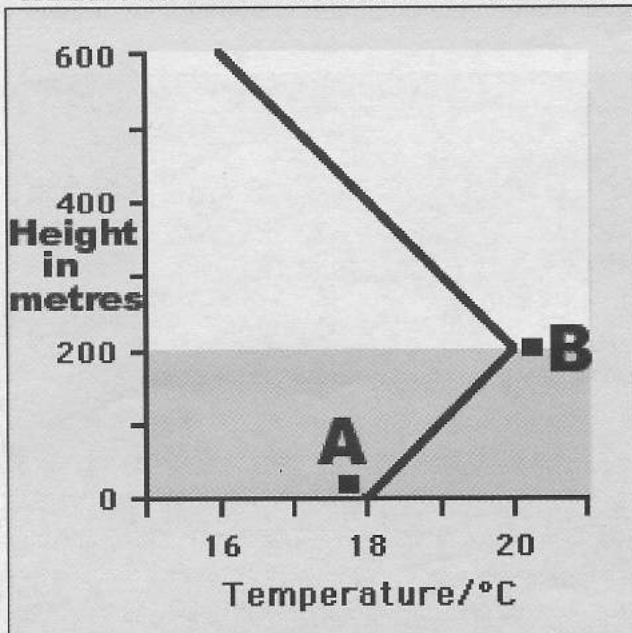
Temperature inversion occurs in valleys during **calm winter nights**. As a result of katabatic air flow, cold air drains down the valley sides at night. The **cold air** accumulates at the **bottom** of the valley. The warm air that was at the bottom of the valley is **displaced** by the cold air and now rests above the cold air. The warm air forms a **thermal belt**. As a result temperatures lower down in the valley are low whilst temperatures higher up are high. (Temperature **increases** with **height** in the valley). This atmospheric condition is known as **temperature inversion** and represents a **negative lapse rate**.

**Frost pockets** may occur on the valley floor as a result of temperature inversion. This occurs when the temperature of the cold air on the valley floor drops to below freezing level.

The sketch below illustrates **temperature inversion**, the **location of the thermal belt**, and the occurrence of **frost**.



GRAPH SHOWING TEMPERATURE INVERSION



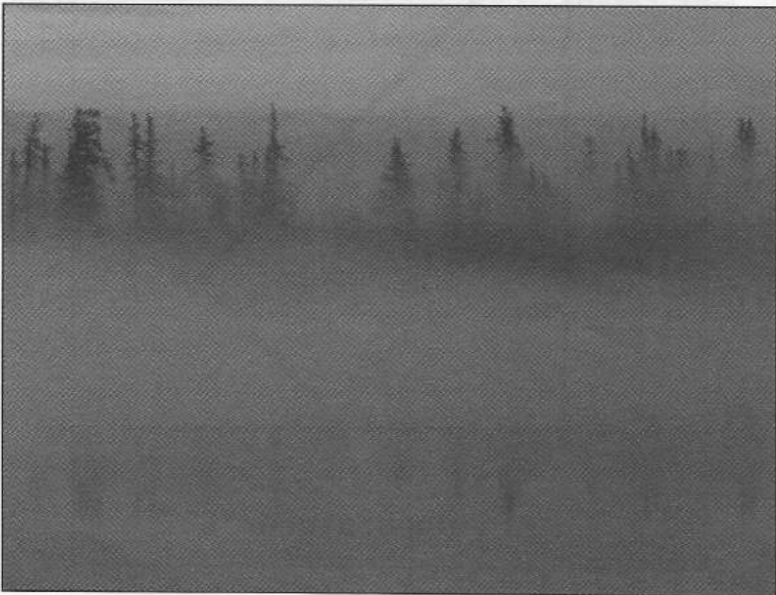
Temperature inversion occurs along the line labelled A - B.

### RADIATION FOG

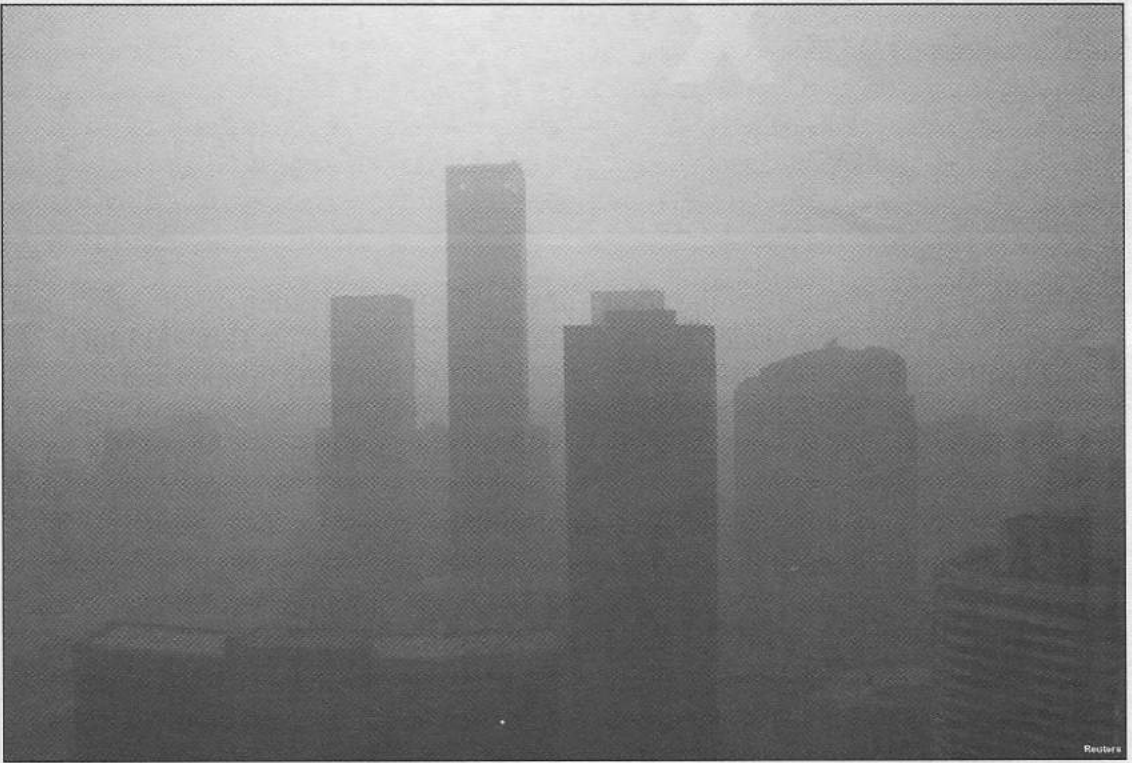
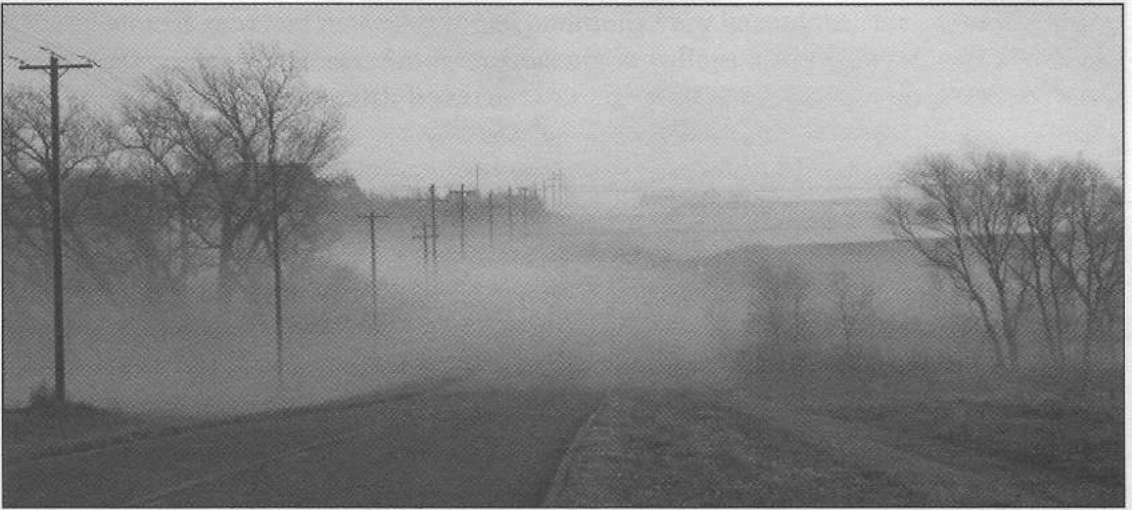
Fog is a **collection of water droplets** suspended in the air near the earth's surface. It is the result of **low level condensation**. Radiation fog forms at **night** during **clear, calm** conditions. At night, the ground surface cools as a result of heat loss by **earth radiation**. The moist air above the ground surface is cooled to **dew point temperature** as a result of direct contact with the cold ground surface. This causes the moisture to **condense** and form fog. Radiation fog usually occurs below the temperature inversion layer. This prevents the fog from rising. Radiation fog varies in depth from one metre to about 300 metres.

**Smog** forms when fog combines with pollutants in the atmosphere. This is a serious problem to settlements located in valleys since the smog is a health hazard.

### IMAGES OF RADIATION FOG

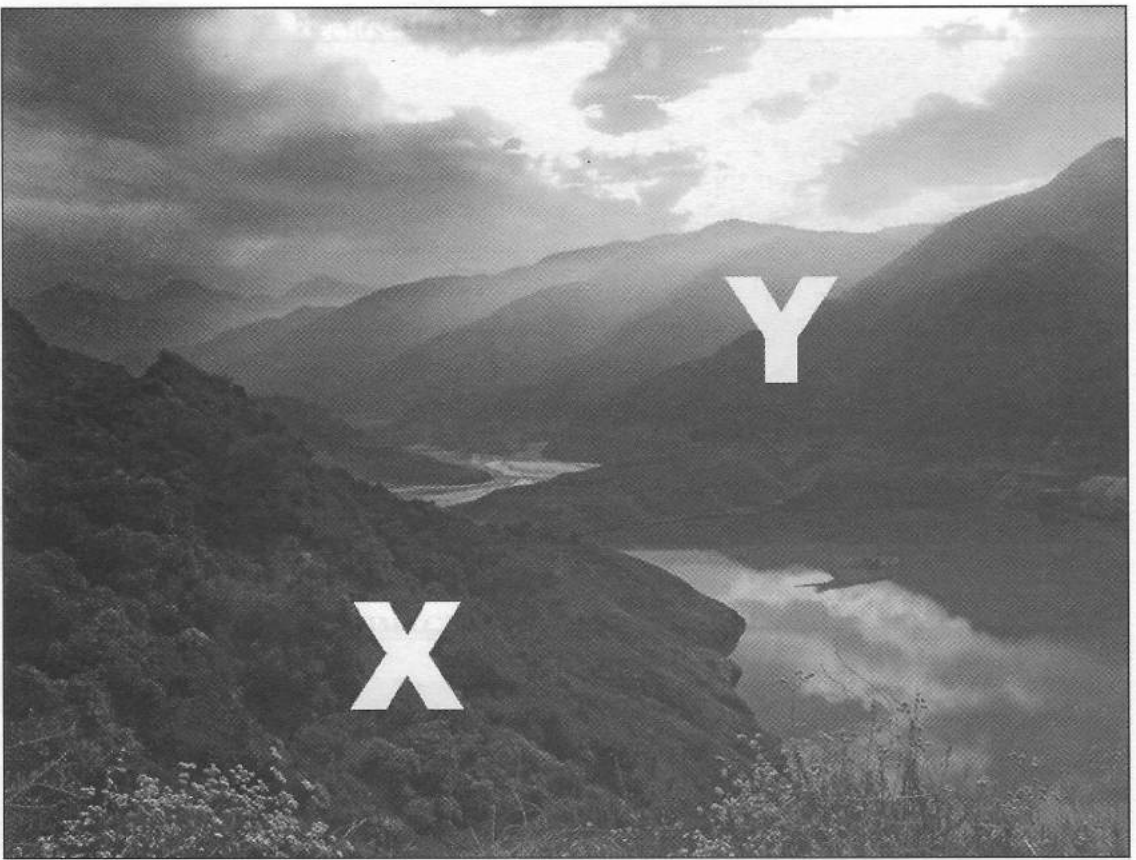


## SMOG CAUSED BY POLLUTION



## THE INFLUENCE OF LOCAL CLIMATES ON HUMAN ACTIVITIES SUCH AS SETTLEMENT AND FARMING

- Slope aspect influences the **density of vegetation**. On the **warmer slope**, there is **greater evaporation** and **less soil water**. As a result vegetation on this slope is **sparse**. On the **cooler slope**, there is **less evaporation** and **more soil water**. **Dense vegetation** occurs on the cooler slope. The photograph below illustrates this. Note the dense vegetation on the cooler slope (X) and the sparse vegetation on the warmer slope (Y).

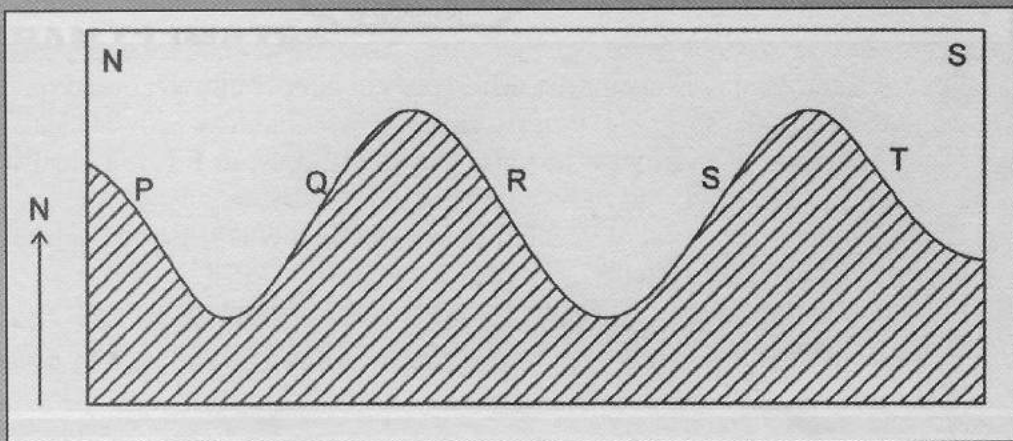


- Slope aspect influences the **choice of sites** for the cultivation of different types of crops. On the **warmer slope**, a fruit farmer will cultivate **thin - skinned fruits** such as grapes because they need a **lot of sunshine** to ripen and sweeten. On the **cooler slope**, a farmer will cultivate **thick - skinned fruits** such as oranges because they can withstand low temperatures.
- Slope aspect influences **urban land use**. There is greater demand for **residential plots** on the **warmer slope**. As a result such plots are more expensive and are generally occupied by **high income residential**.
- Temperature inversion in the valley is a **climatic hazard** on a local scale. On the valley floor the temperatures are very low and frost may occur. Therefore a farmer will cultivate **frost resistant crops**, for example, sugar beet, wheat etc. on the valley floor.
- The cold air that accumulates at the bottom of the valley as a result of katabatic air flow is **dense** and **stable**. As a result pollutants given off by heavy industries, domestic fires and motor vehicles are **trapped** in the valley at night. The pollutants form a **blanket** over the valley. This is a **health hazard** to people living in the valley. Pietermaritzburg in KwaZulu - Natal is a good example of a city where this condition occurs in winter. During the day the pollutants are **released** from the valley as a result of **anabatic winds**.
- As a result of temperature inversion which causes very cold conditions at the bottom of the valley, people generally settle **midway** up the valley slope so that they are in the **thermal belt** where temperatures are relatively high.

- The **radiation fog** that occurs at the valley bottom can **reduce visibility** to almost zero and makes driving conditions very hazardous. The fog results in numerous accidents. **Smog** that occurs in valleys also results in **poor visibility** and is a serious **health hazard**.

## ACTIVITY 20

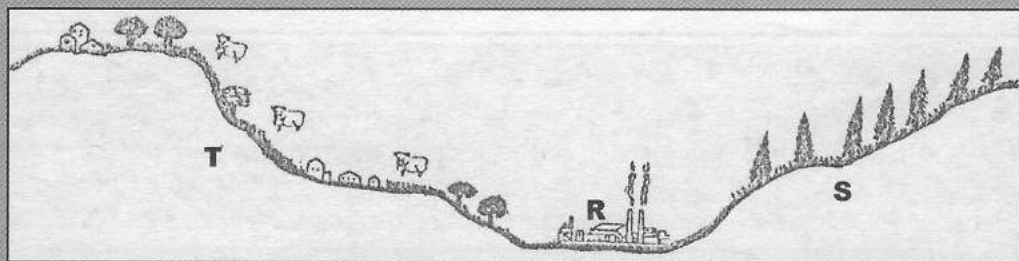
Study the sketch showing a landscape in the south Western Cape and answer the questions that follow.



1. What type of climate does the south Western Cape experience?
2. Name the weather system that is responsible for this type of climate.
3. Does this weather system affect climate on a macro, meso or micro scale?
4. Why is this type of climate ideal for the cultivation of vineyards?
5. Name **two** northward facing slopes.
6. Name **three** southward facing slopes.
7. Which slope, P or Q, is warmer?  
Give a reason for your answer.
8. Which slope, R or S, is more suitable for the cultivation of grapes?  
Give a reason for your answer.
9. Which slope, S or T, is more suitable for high class residential development?  
Give a reason for your answer.
10. Explain why aspect of a slope does not have a significant effect on the temperature of places lying within the tropics.

## ACTIVITY 21

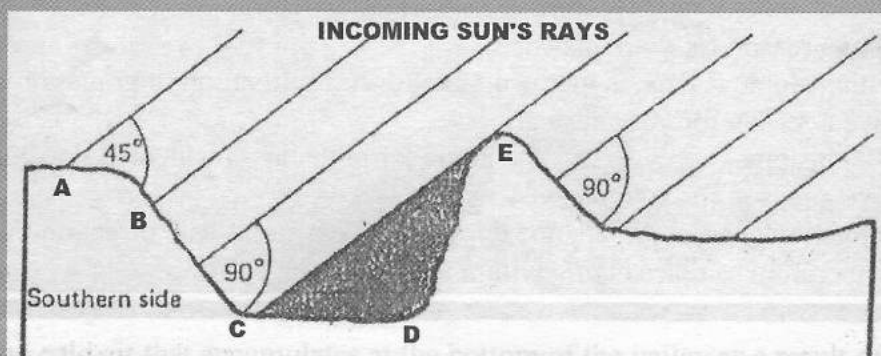
Study the diagram of a valley situated at  $35^{\circ}$  N and answer the questions that follow.



1. Describe and give reasons for the differences in temperature recorded on slopes S and T.
2. From a climatic point of view, explain why the land use at R is not ideally located.
3. Explain how the removal of vegetation from slope S will affect the natural environment and ecosystems.
4. Explain how the land use at R contributes to the formation of smog.
5. Name the winds that occur in this valley on a cold winter night.

## ACTIVITY 22

Refer to the sketch below and answer the questions set.



1. Which of the following surfaces is most intensely heated?
  - 1.1. A - B
  - 1.2. B - C
  - 1.3. C - D
  - 1.4. D - E
2. Which of the following factors is responsible for the above (answer 1)?
  - 2.1. A: the area receives the oblique rays of the sun

- 2.2. B: the area is situated near the equator
  - 2.3. C: the area lies at a lower altitude
  - 2.4. D: the area receives the vertical rays of the sun
3. Examine the areas marked B - C; C - D and D - E and choose a specific area suitable for the cultivation of each of the following:
- vineyards
  - sugar beet
- Give a reason for your choice.

## URBAN CLIMATES

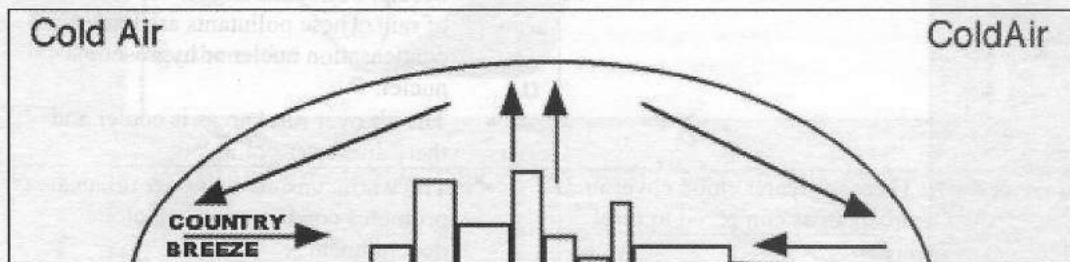
An urban area has a climate that is different from that of the surrounding rural area. An urban area is a man - made creation. Man has destroyed the natural vegetation and replaced it with a “**concrete jungle**”. As a result of this, the climate of the newly created surface has been modified.

## REASONS FOR DIFFERENCES BETWEEN RURAL AND URBAN CLIMATES

CLIMATIC FACTOR	URBAN AREAS COMPARED TO RURAL AREAS	REASONS FOR THESE DIFFERENCES
Temperature	Urban areas experience higher temperatures. Mean annual temperatures are higher by 1 - 5° C.	<ul style="list-style-type: none"> <li>• Refer to the next section for a detailed explanation.</li> </ul>
Rainfall	Urban areas receive more rainfall than the surrounding rural areas.	<ul style="list-style-type: none"> <li>• The air over an urban area is warm and therefore unstable. This causes the air to rise and condense.</li> <li>• There are more pollutants over an urban area. This is caused by the smoke given off by heavy industries, exhaust fumes of motor vehicles, domestic fires and mining activities. These pollutants act as nuclei around which condensation occurs. Pollutants trigger the formation of rain. These pollutants are known as condensation nuclei or hygroscopic nuclei.</li> <li>• The air over rural areas is cooler and there are fewer pollutants.</li> </ul>
Cloud cover	There is greater cloud cover in urban areas compared to rural areas.	<ul style="list-style-type: none"> <li>• The warm, unstable air over urban areas promotes condensation and cloud development.</li> <li>• The pollutants over an urban area act as hygroscopic nuclei around which condensation occurs. This leads to cloud formation.</li> <li>• The air over rural areas is cooler and there are fewer pollutants.</li> </ul>

<b>Fog and smog</b>	There is more fog and smog in urban areas.	<ul style="list-style-type: none"> <li>• There are more hygroscopic nuclei in an urban area. Low - level condensation around these particles results in the formation of fog and smog.</li> <li>• There are fewer hygroscopic particles in rural areas.</li> </ul>
<b>Wind speed</b>	Wind speed is lower in urban areas compared to rural areas. Turbulence is greater in urban areas.	<ul style="list-style-type: none"> <li>• The tall buildings in urban areas act as windbreakers. They reduce wind speed.</li> <li>• The tall buildings on either sides of a street cause air flow to be channelized in a specific direction. This causes turbulence of air.</li> <li>• The low buildings and vast open spaces in rural areas result in higher wind speeds.</li> </ul>
<b>Insolation (Incoming solar radiation)</b>	There is less insolation over urban areas compared to rural areas.	<ul style="list-style-type: none"> <li>• There is a greater amount of pollutants and cloud cover over urban areas. The pollutants and clouds absorb, reflect and scatter some of the heat energy. As a result less solar energy reaches the surface of the urban area.</li> </ul>
<b>Water vapour and relative humidity</b>	There is less water vapour over urban areas. The relative humidity is lower compared to the rural areas.	<ul style="list-style-type: none"> <li>• There is limited exposed soil and vegetation in urban areas because much of the ground space is occupied by buildings and tarred streets. Much of the rainfall escapes as run - off. Hence there is little evaporation and therefore less moisture in urban areas.</li> <li>• In rural areas, there is more evaporation which results in a higher relative humidity.</li> </ul>
<b>Pollution and dust particles</b>	There is a greater concentration of pollutants and dust particles over an urban area compared to the rural area.	<ul style="list-style-type: none"> <li>• Heavy industries, motor vehicles, domestic fires, mining activities, and building activities release large quantities of smoke and dust into the air over a city. The pollutants create more hygroscopic nuclei in the atmosphere.</li> </ul>

The high temperature in the city results in the warming of air. This unstable air has a tendency to rise thus creating a low pressure area over the city. This results in the inflow and convergence of cooler air from the surrounding rural area. This cooler air is referred to as the **“country breeze”**. The sketch below illustrates this circulation.



**REASONS FOR URBAN AREAS HAVING HIGHER TEMPERATURES THAN THE SURROUNDING RURAL AREAS (FACTORS THAT PROMOTE URBAN HEAT PRODUCTION)**

### **The city has a limited supply of exposed soil and vegetation**

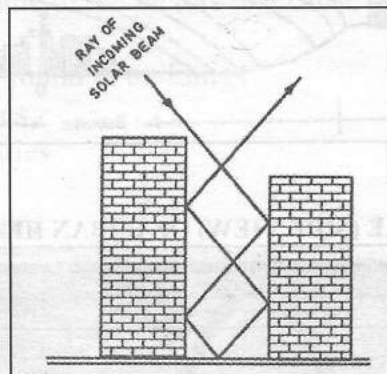
A city has **limited exposed soil and vegetation** because much ground space is occupied by buildings and tarred streets. In the surrounding rural area some of the incoming solar radiation is used up during the processes of **transpiration, evaporation** and **photosynthesis**. Hence less heat is available to warm the atmosphere in rural areas. In the **urban areas** there is **less vegetation and exposed soil**. Hence heat energy is not used up in this way. Therefore more heat energy is available to warm the urban environment. In urban areas much of the **rainfall** escapes as **run - off** on roofs and tarred streets. Hence there is little evaporation and **little evaporational cooling**. In rural areas much of the rainfall infiltrates the surface. Therefore there is **more evaporation** and evaporational cooling which reduces temperature in **rural areas**.

### **A city is constructed from concrete, steel and similar material**

The city may be described as a “**concrete jungle**” that has been created by man. **Concrete** in urban areas is able to store **three times** more heat than the same volume of soil or vegetation. Concrete absorbs heat slowly during the day and releases it slowly at night thus raising temperatures considerably. In rural areas **soil** absorbs **heat rapidly** and gives it off **rapidly** at night thus reducing temperatures. Cities contain a large number of **black streets** which absorb a lot of heat and give rise to high temperatures. In rural areas **soil and vegetation** are **poor conductors** of heat.

### **A city has a distinctive building geometry**

The **walls of tall buildings** in a city enable **multiple reflection** of sunlight to occur. As a result more heat is absorbed by the buildings. The sketch below illustrates this.



The **tall buildings** and **high building density** in urban areas **increase the surface area** for heat absorption. Heat is absorbed by the roofs and walls of buildings. The only surface area for heat absorption in rural areas is the **ground space** which is far less than the area provided by the roofs and walls of buildings. **Tall buildings** also serve as **wind breakers** thus reducing wind speed in a city. Hence less heat flows out of the city thus raising city temperatures.

### Certain activities in the city generate heat

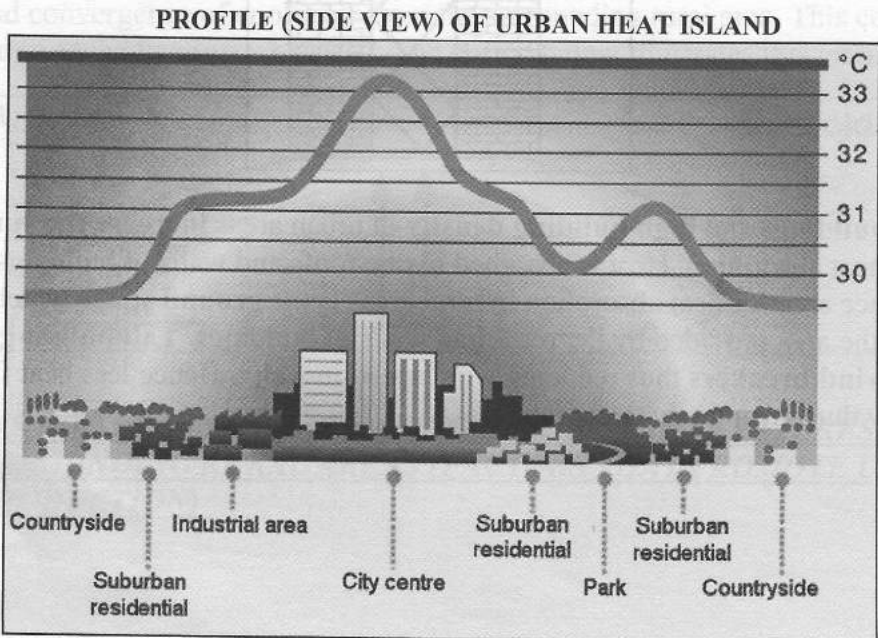
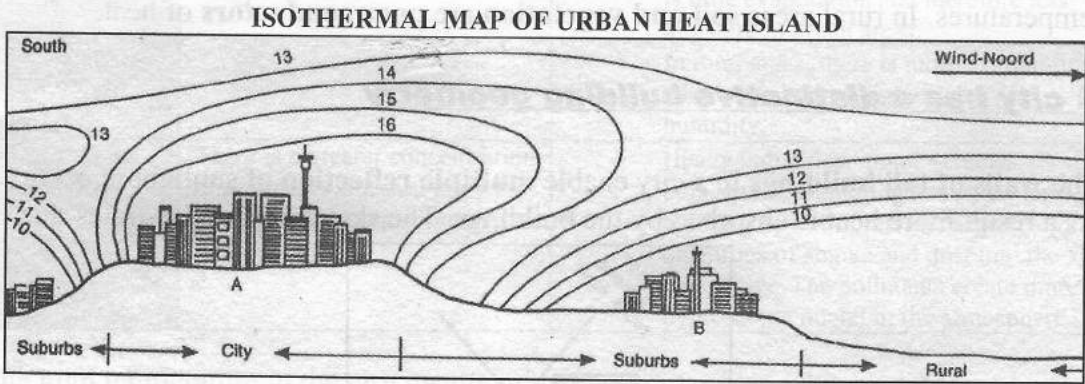
The city produces heat directly because of the **heavy industries**, **motor vehicles**, **street lights** and **household appliances**. These increase the temperature of the city. **Body heat** also contributes to raising city temperatures.

### Certain activities in the city produce pollutants

**Industries** and **motor vehicles** release large quantities of pollutants. In some cities **mining activities** release mine dust into the atmosphere. These pollutants form a **dust dome** over the city. The pollutants absorb heat given off especially at night thus raising city temperatures. Heat is **trapped** within the dust dome. The dust dome, therefore, creates a **blanket (greenhouse)** effect.

## **URBAN HEAT ISLANDS - CAUSES AND EFFECTS**

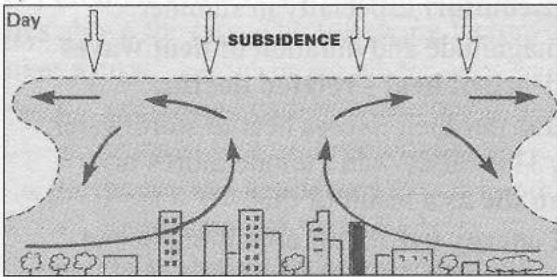
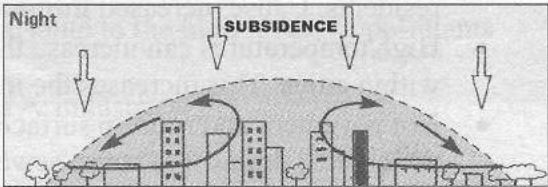
The **city** is regarded as a **heat island** because it has higher temperatures than the surrounding rural area. The heat island extends horizontally and vertically. The vertical extension is the result of the rising of heated air. Urban heat islands exist throughout the year, but their effect is more pronounced at **night** and in **winter**. The **isothermal map** below illustrates a heat island.



- The **highest temperatures** are recorded in the **city centre (CBD)**.
- The **temperature decreases** as one moves away from the city centre.

### THE URBAN HEAT ISLAND DURING THE DAY AND NIGHT

The table below **illustrates** and **describes** the differences between the urban heat island during the day and at night.

DAY	NIGHT
<ul style="list-style-type: none"> <li>• The heat island grows <b>vertically</b> as a result of the <b>rising of heated air</b>.</li> <li>• The trapped heat is <b>less concentrated</b>.</li> <li>• Pollutants are dispersed over a <b>greater area</b>.</li> <li>• The heat island assumes a <b>mushroom shape</b>.</li> </ul>	<ul style="list-style-type: none"> <li>• The cooling of the air at night causes the <b>bubble of warm air</b> to become <b>denser and shallower</b>.</li> <li>• The trapped heat is <b>more concentrated</b>.</li> <li>• The heat island assumes a <b>dome shape</b>.</li> <li>• Pollutants are <b>concentrated</b> within the dome.</li> </ul>
	

### CAUSES OF URBAN HEAT ISLANDS

- The following are some of the factors that cause urban heat islands:
  - The concrete found in buildings
  - Motor vehicles
  - Heavy industries
  - Lights
  - Glass structures
  - Body heat
  - Tarred streets
  - Artificial heating
  - Air conditioning
  - Combustion of fossil fuels
  - Lower wind speeds which cause heat buildup
  - High concentration of pollutants which trap heat
  - Very little evapotranspiration in urban areas
  - Large concentration of people
  - Many buildings have dark surfaces. Dark surfaces absorb more **heat**.

Note that in reality heat islands display an **irregular shape** because of the following factors:

- The city having an irregular shape.
- Uneven urban expansion.
- The presence of a river.
- Commercial decentralization.
- Variation in altitude within the city.

## **EFFECTS OF URBAN HEAT ISLANDS**

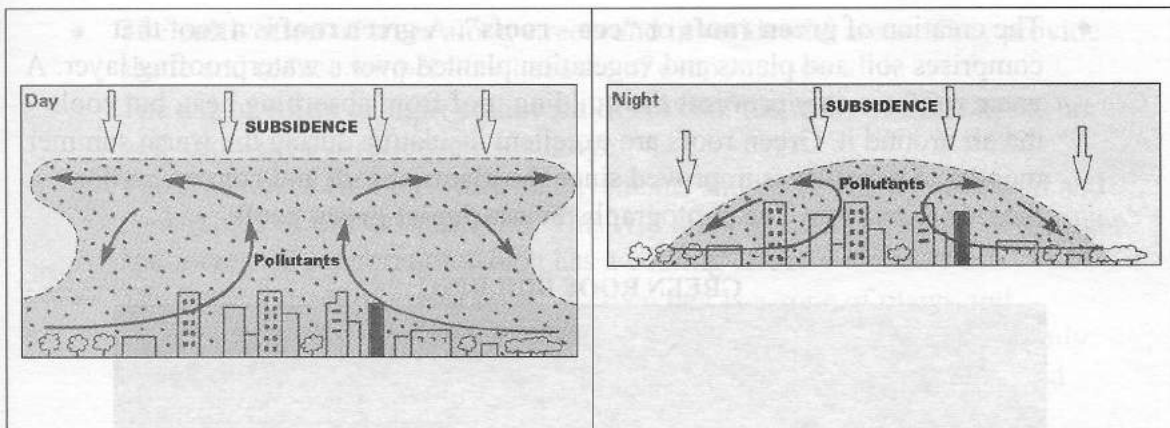
Urban heat islands impact on both **urban dwellers** and the **environment**. These include:

- Cause **higher rainfall** and **greater thunderstorm activity** over urban areas.
- **Reduces the formation of ice and snow**, which is positive.
- High temperatures impact negatively on the health and welfare of urban residents. Cause increased **human discomfort** especially in summer.
- High temperatures can increase the magnitude and duration of **heat waves** within cities. This increases the incidence of **heat - related deaths**.
- Hot pavement and rooftop surfaces transfer their excess heat to stormwater, which then drains into storm sewers. This raises water temperatures in streams, rivers, ponds, and lakes. **Fish die** as a result of this.
- High temperatures lead to **increased energy use** for air conditioning and refrigeration.
- High temperatures **increase** the rate at which **ozone** forms.
- They **increase the length of the growing season**, which is positive.
- Lead to the **development of smog** which causes poor visibility. Smog is also a health hazard.

## **CONCEPT OF POLLUTION DOMES - CAUSES AND EFFECTS**

A pollution dome is a **mass of polluted air** that extends over a city. The polluted air is **trapped** because of an **inversion layer** situated above it. Strong winds may elongate the dome into a **pollution plume**. Pollution domes are similar to urban heat islands. Urban heat islands emphasize the **trapping of heat** whilst pollution domes focus on the **trapping of pollutants** over the city. The **apex** of the pollution dome corresponds with the **central business district**. It is also known as a **dust dome**. The pollution dome is composed of **smoke, dust, soot and other pollutants**. The **subsidence of air** in the upper atmosphere promotes the development of a pollution dome. The pollution dome is **better developed in winter** because of the **stronger subsidence** over the city.

<b>POLLUTION DOME : DAY</b>	<b>POLLUTION DOME: NIGHT</b>
<ul style="list-style-type: none"> <li>• The pollution dome extends <b>vertically</b> over the city.</li> <li>• As a result pollutants are <b>dispersed</b> over a greater area.</li> </ul>	<ul style="list-style-type: none"> <li>• The pollution dome is <b>compressed</b> and lies closer to the surface of the city.</li> <li>• As a result pollutants are <b>more concentrated</b>.</li> </ul>



### CAUSES OF POLLUTION DOMES

A pollution dome forms when pollutants are trapped beneath an inversion layer that lies above the city. The following factors contribute to the high levels of pollutants over a city:

- smoke and carbon emissions from heavy industries
- exhaust fumes of motor vehicles
- household appliances
- combustion of fossil fuels
- dust released by mining and building activities.

### EFFECTS OF POLLUTION DOMES

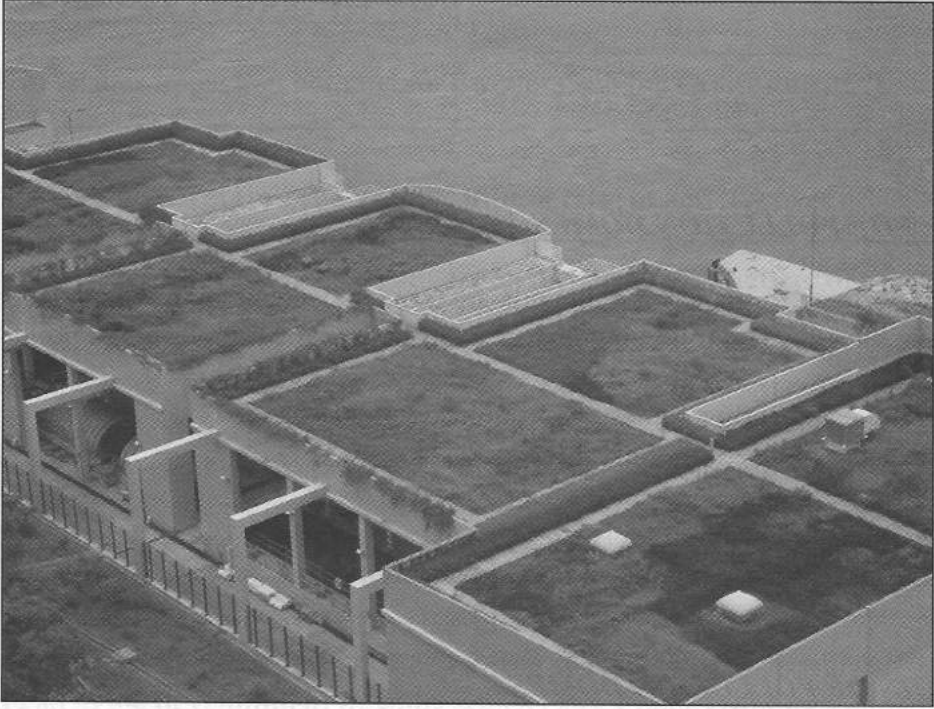
- Cause **greater cloud cover** and **rainfall** over cities.
- **Severe thunderstorms** may occur in summer.
- Pollutants absorb incoming solar radiation during the day. This **raises city temperatures**.
- Pollutants **absorb heat** given off by earth radiation at night. This also raises city temperatures.
- Pollutants have an adverse effect on the health of humans. Smoke emissions cause **respiratory disease**.
- Condensation around pollutants results in the formation of **smog**. Smog results in **poor visibility** and is a **health hazard**.
- Pollutants lead to the formation of **acid rain** which causes **corrosion of buildings**. Acid rain **stunts the growth of plants** and **causes fish to die**.
- Emission of **greenhouse gases** contributes to **climate change**.

### **STRATEGIES TO REDUCE THE HEAT ISLAND EFFECT**

- Use of **light - coloured concrete** in the construction of buildings, streets, pavements and parking lots. Light - coloured concrete has a **high albedo**. This means that much of the incoming solar radiation is **reflected** and less heat is absorbed.

- The creation of **green roofs** or “**eco - roofs**”. A green roof is a roof that comprises soil and plants and vegetation planted over a waterproofing layer. A green roof not only prevents the building roof from absorbing heat, but cools the air around it. Green roofs are excellent insulators during the warm summer months. Air quality is improved since the plants absorb and convert carbon dioxide to oxygen. The photographs below **depict green roofs**.

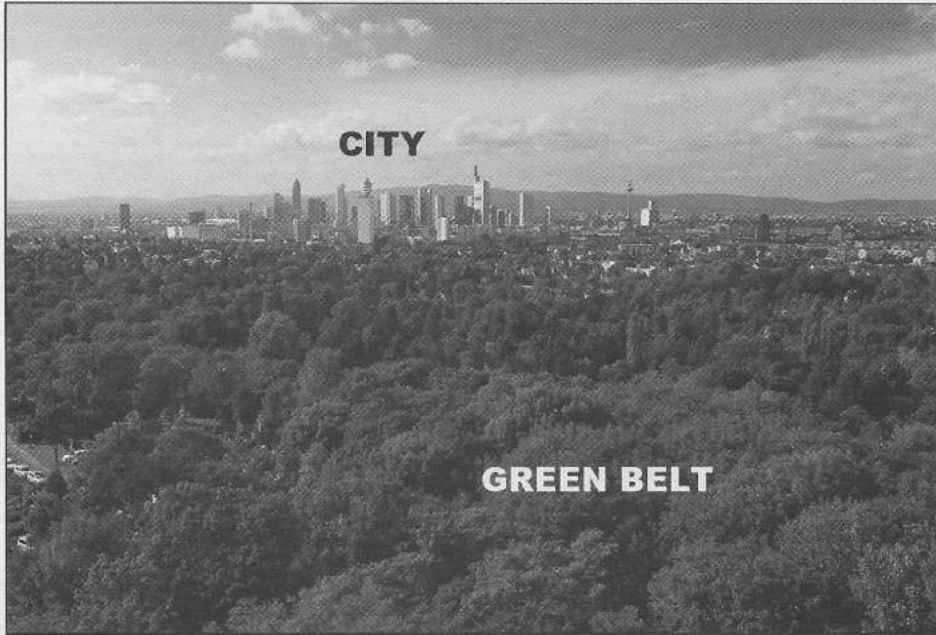
**GREEN ROOF BUILDING**



**GREEN ROOF HOUSE**



- The **cultivation of trees** along streets and in residential areas. They provide shade and reduce temperature because of evapotranspiration.
- The use of **white or light colour paints** to coat the walls of buildings. This will allow greater reflection of sunlight.
- The creation of **cool pavements**. Pavements should be **lightly coloured** and constructed of **porous material**. This will allow greater reflection of sunlight and increased evaporation which has a cooling effect
- The development of **green belts**. A green belt is a zone of plants and vegetation on the boundary of an urban settlement. The green belt not only reduces the overall temperature of the city but also prevents uncontrolled urban expansion.

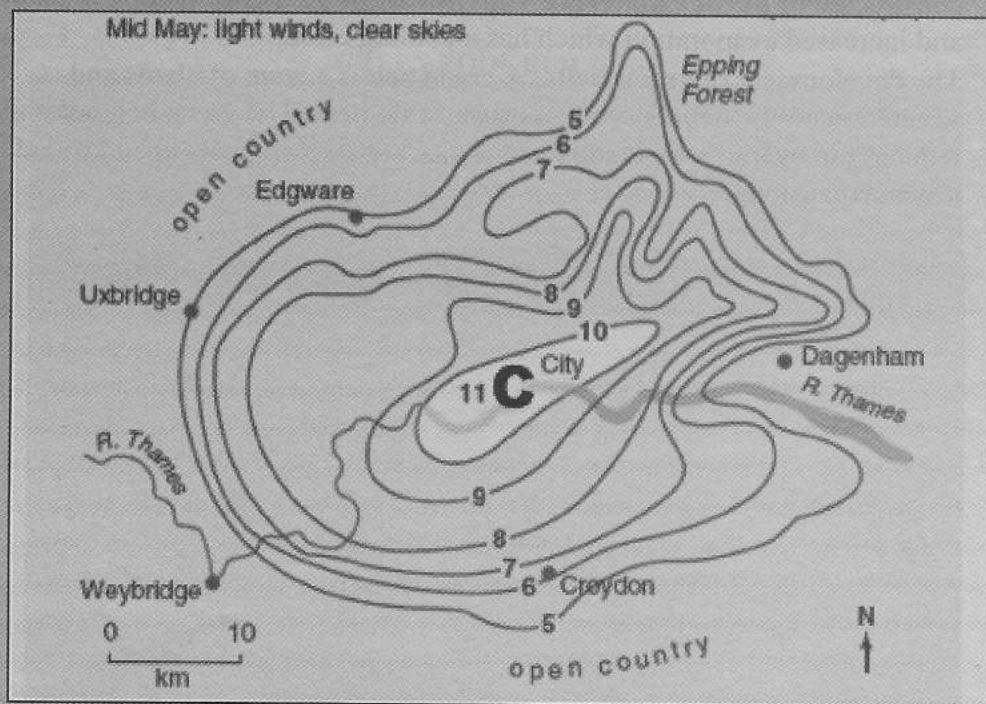


- The development of **cool roofs**. A cool roof is one that is lightly coloured and constructed from reflective material. This greatly reduces the amount of heat absorbed by the roof.
- The creation of **open spaces** and **parks** within the city.
- **Heavy industries** should be located far away from the built up area.
- The **decentralization of commercial functions** will result in fewer vehicles entering the central business district.
- **Roof sprinkling**. Sprinklers on the roof wet the surface so that the air around it cools through evaporation.
- Motor vehicles should be equipped with **catalytic converters**. These purify exhaust fumes.
- The use of **park and ride facilities** and **public transport** also reduces the number of vehicles in the central business district.

Albedo refers to the ratio between **heat energy received** and **heat energy reflected**. The amount of heat energy reflected depends on the **colour** of the object. Objects that are light in colour reflect a lot of heat. They are said to have a **high albedo**. A good example is **snow**. Objects that are dark in colour reflect very little heat. They are said to have a **low albedo**. They absorb most of the heat. A **tarred street** is a good example.

## ACTIVITY 23

Study the isothermal map below which shows the heat island of London and answer the questions that follow.

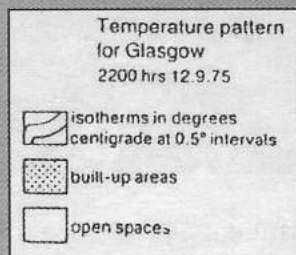
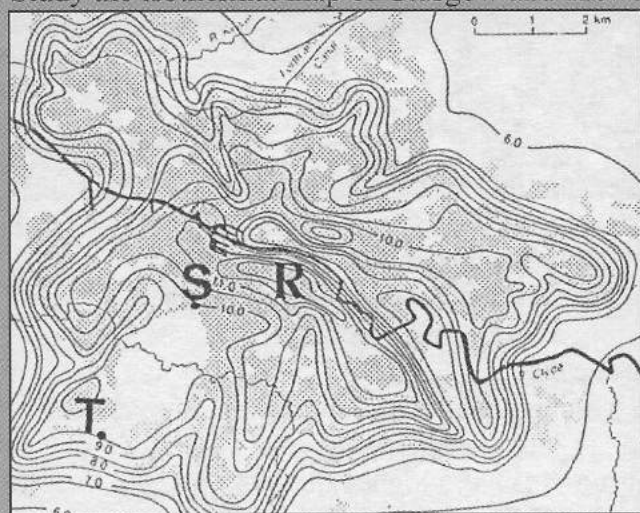


1. Explain the term urban heat island.
2. During which season is the heat island better developed?
3. The temperature recorded at Epping Forest is....
  - 3.1. 5° C
  - 3.2. 7° C
  - 3.3. 11° C
  - 3.4. 14° C
4. The temperature range between the city centre (C) and Uxbridge is....
  - 4.1. 7° C
  - 4.2. 10° C
  - 4.3. 6° C
  - 4.4. 12° C
5. The lines drawn on this map to represent these temperatures are...
  - 5.1. Isobars
  - 5.2. Isotherms
  - 5.3. Isohyets
  - 5.4. Isolines
6. The steepest temperature gradient is recorded between the city centre (C) and....
  - 6.1. Uxbridge
  - 6.2. Croydon
  - 6.3. Edgware
  - 6.4. Weybridge

7. The heat island is most intensive over....
  - 7.1. Uxbridge
  - 7.2. Croydon
  - 7.3. Dagenham
  - 7.4. The city centre
8. With the aid of a cross section (side view), describe the movement of air in this heat island.
9. Suggest **three** reasons for the temperature recorded over the city centre (C).
10. Explain why the pollution level over the city will be higher during the winter and spring months.
11. Evaluate the effect of heat islands on city planning.

## ACTIVITY 24

Study the isothermal map of Glasgow and answer the questions that follow.



1. What evidence is there to show that the temperature changes rapidly as the edge of the city is reached?
2. What effect does the Clyde River Valley have on the urban temperature pattern?
3. Describe the temperature conditions in the city centre (R) and suggest **two** reasons for the temperature contrast between this area and the rest of the city.
4. Explain why the temperature decreases gradually between the points marked S and T.
5. Besides the creation of open spaces, suggest **two** other measures that may be adopted to reduce the urban heat island effect.
6. Give **two** reasons for the heat island having an irregular shape.

## ACTIVITY 25

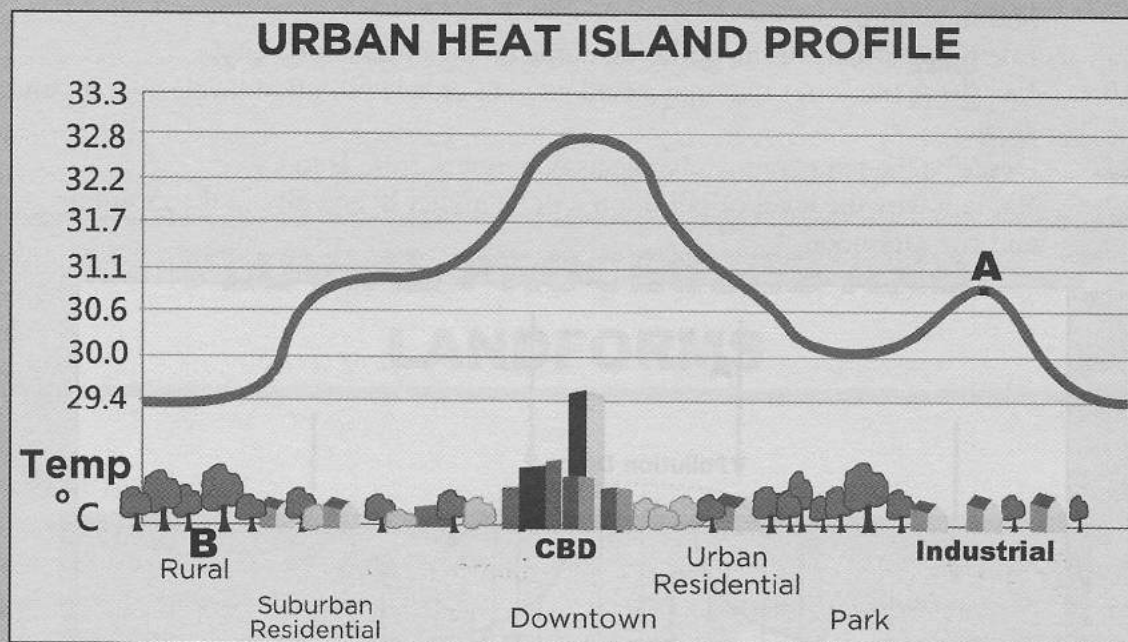
Study the photograph showing an urban settlement and answer the questions set.



1. Differentiate between the terms “urban heat island” and “dust dome”.
2. Identify the urban land use zone where the heat island is most intensely developed.
3. Give **two** reasons for this (refer question 2).
4. Explain **two** ways in which the building labelled A contributes to urban heat production.
5. Which of the buildings labelled A and B has a higher albedo?
6. What effect does this (refer question 5) have on city temperatures?
7. Suggest **two** modifications that may be made to the building labelled A to reduce the urban heat island effect.
8. In what way does the feature labelled E assist in reducing the city temperature?
9. Describe the temperature change from A to D.
10. State a measure (evident in the photograph) that has been adopted to reduce the city temperature.
11. In what way does the feature labelled C contribute to reducing the urban heat island effect?

## ACTIVITY 26

Study the urban heat island profile and answer the questions set.



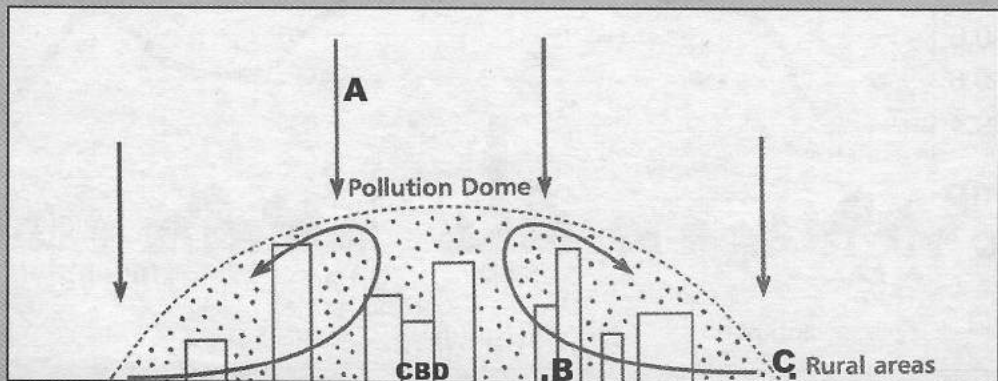
1. What is a heat island?
2. What is the highest temperature recorded in the CBD?
3. Describe the temperature change as one moves away from the CBD.
4. Explain **two** factors (evident in the profile) that contribute to high temperatures in urban settlements.
5. What effect do parks have on urban temperatures?
6. Give **two** reasons for this (refer question 5).
7. Give **two** reasons for the lower temperatures in the area labelled B.
8. List **four** effects of urban heat islands on the climate of cities.
9. Explain the term "cool pavement".
10. Is the study of city climate an aspect of microclimate or macroclimate?

## ACTIVITY 27

Study the sketch below showing a pollution dome over an urban settlement and answer the questions set.

1. What is a pollution dome?
2. Name the air movement labelled A.
3. What is the significance of this air movement (refer question 2) in the formation of a pollution dome?
4. During which season is the pollution dome better developed?

5. Give a reason for your answer to question 4.
6. Does the sketch represent a night situation or a day situation?
7. Give a reason for your answer to question 6.
8. List **three** sources of pollution that contribute to the development of a pollution dome.
9. List **three** effects of the pollution dome on the climate of a city.
10. List **three** measures that may be adopted to reduce pollution levels over urban areas.
11. Describe the temperature change as one moves from B to C.
12. Explain why the level of pollution will be higher over a city in the morning and late afternoon.



## APPLICATION OF GIS TO CLIMATOLOGY AND METEOROLOGY

- Meteosat satellite images play an important role in meteorology and climatology.
- These satellites carry several instruments that measure the **condition of the atmosphere**.
- Satellite images assist in **weather forecasting**.
- Images of **rising sea levels** and **shrinking of glaciers** give an indication of **global warming** and **climate change**.
- Images of **cloud cover** help to predict the **intensity of rainfall** in different areas.
- This information is important to **farmers, people living in low - lying areas, road users** etc.
- Meteosat images of weather systems are important to people not only to understand **prevailing weather conditions** but to **predict future weather conditions**.
- They also assist in **tracking the path of weather systems** so that early **warning signals** may be issued to people in affected areas.
- It is possible to identify possible **fire hazard areas** by studying Meteosat images of **global temperatures**.